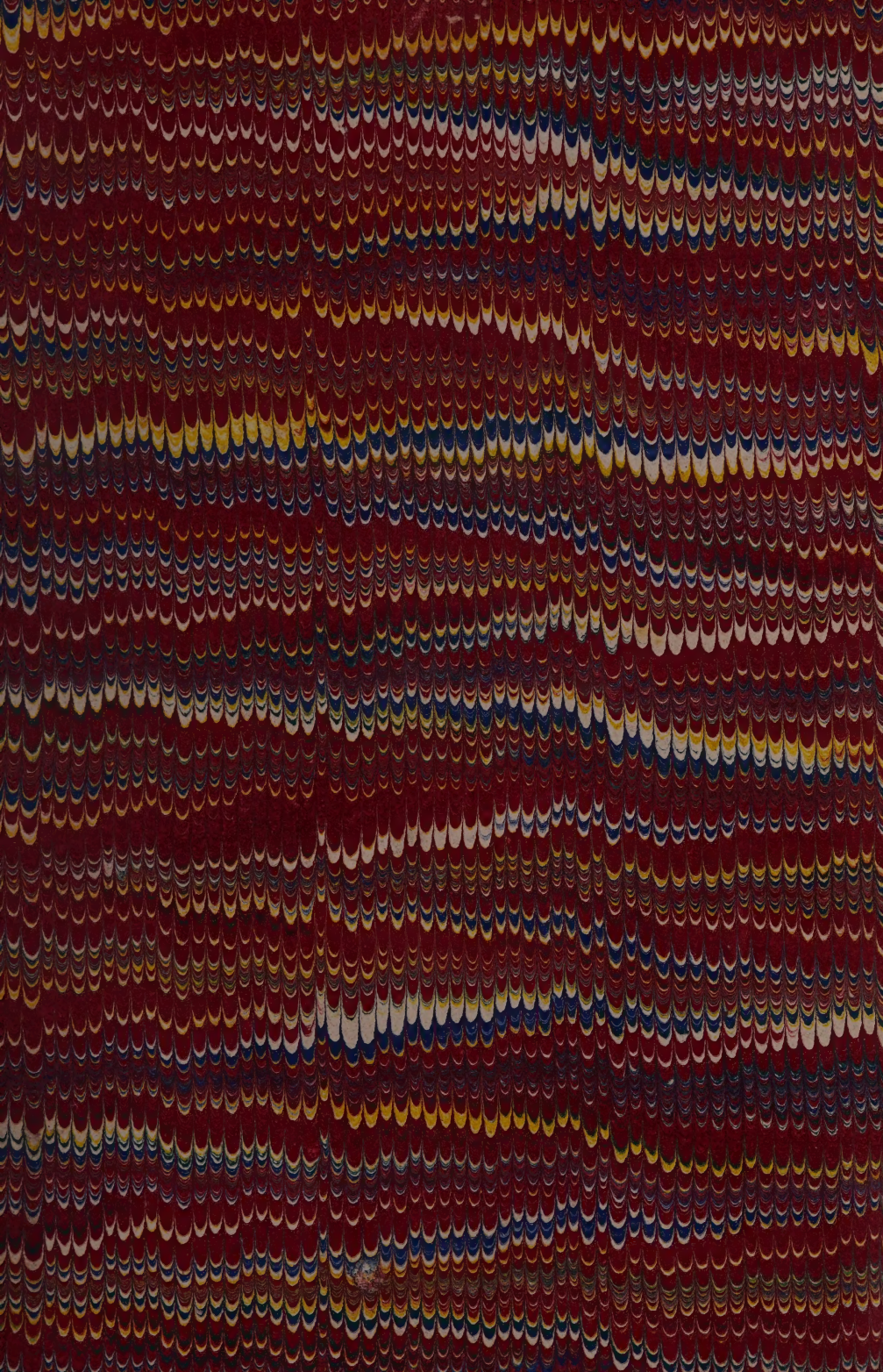






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LECTURES

14 March 1849

ON

COMPARATIVE EMBRYOLOGY,

DELIVERED BEFORE

THE LOWELL INSTITUTE, IN BOSTON,

DECEMBER AND JANUARY, 1848-9,

BY

LOUIS AGASSIZ,

PROFESSOR OF ZOOLOGY AND GEOLOGY IN THE LAWRENCE SCIENTIFIC SCHOOL,
CAMBRIDGE UNIVERSITY.

PHONOGRAPHIC REPORT, BY JAMES W. STONE, A. M., M. D.

President of the Boston Phonographic Reporting Association, and of the Boylston Medical Society.

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1849.

THE
Lectures
being
delivered

COMPARATIVE EMBRYOLOGY,

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BOSTON:

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1858.

PREFACE.

WE feel both pleasure and pride in being able to present to the public the following Course of Lectures. It is the first enterprise of the kind in this city, and has therefore been attended with unusual trouble and expense.

EMBRYOLOGY has but recently become the subject of scientific investigation. Few persons have as yet entered upon it, and in this country it may be considered as entirely new; but it is destined to have a most important influence in the future progress of Zoölogy, and greatly to modify the present classification of animals. Prof. AGASSIZ has embodied in his Lectures all that has been hitherto done abroad, and has added numerous observations of his own, made in this country, and in a form at once highly scientific and so illustrated, as to be interesting to the common reader. The application here made of Embryology to the improvement of the classification of animals is peculiarly his own, as he has shown in his fourth Lecture.

The point of the Lectures is to demonstrate that a natural method of classifying the animal kingdom may be attained by a comparison of the changes which are passed through by different animals in the course of their development from the egg to the perfect state; the changes they undergo being considered as a scale to appreciate the relative position of the series.

The language has been retained almost precisely as delivered by the Professor, because, although in many instances it wears a foreign idiom, yet it is peculiarly expressive, and possesses a charm which would be lost in the attempt to reduce it to Saxon phrases.

In proof of the fullness and accuracy of Dr. STONE's phonographic report, and also of the value of the phonographic system, we are enabled to state that several gentlemen had the curiosity to compare a portion of manuscript which the Professor had read, in one lecture, with the report of it; when it was found that every word appeared precisely as written, except that one word was missing, which the Professor stated he had purposely omitted in reading.

Boston, January, 1849.

LECTURES ON COMPARATIVE PHYSIOLOGY.

A course of twelve Lectures on *Comparative Physiology*, now being delivered by Prof. JEFFRIES WYMAN, before the Lowell Institute, will also be reported in full and published in the *Traveller*, illustrated by diagrams. The following is the Programme of this course:

LECT. I.—General Properties of Living Beings.

“ II.—Locomotion—Skeleton.

“ III.—Muscular Action.

“ IV.—Comparative Anatomy—Teeth.

“ V.—Digestion.

“ VI.—Absorption and Circulation.

“ VII.—Respiration.

“ VIII.—Nervous system—Nerves and Spinal Marrow.

“ IX.—Brain.

“ X.—Senses—Touch, Taste.

“ XI.—Smelling, Hearing.

“ XII.—Vision.

PROF. AGASSIZ'S

LECTURES ON EMBRYOLOGY,

DELIVERED BEFORE THE LOWELL INSTITUTE — 1848-9.

LECTURE I.

The time has past when it was possible to doubt that there is order in Nature, when the existence of a general system regulating the whole creation could be questioned. However, it has been only step by step that man has acquired an insight into this plan. Knowledge was to be gained before this wonderful arrangement of nature could be understood. And it was not at once fully understood. Understanding has been acquired gradually, successively and with difficulties. However, now we have sufficient data to be able to satisfy ourselves that the various views which have been brought forward respecting the order of nature are not altogether fanciful, that they are not mere artificial means to assist us in our investigations. We can be satisfied that they correspond more or less to nature. We have the positive hope that they will one day correspond entirely to the natural phenomena, when we see how the investigations which are carried on in different directions by different authors go on, converging gradually, assisting each other, and harmonising subjects which at first seemed entirely obscure, if not entirely inaccessible.

The first attempts to an illustration of the relations which exist among the natural phenomena—which exist in particular in the animal kingdom—were traced from external characters. It was from external appearances that scientific men in the beginning tried to combine animals, as it seemed to them they resembled each other most.

But the simple investigation of these external characters was not sufficient. Mistakes were made under the impression that the right thing had been found. Animals, for instance, like the

whale, were placed among fishes; though now it is very well known that those animals have no relation to each other—do not even belong to the same class. Crocodiles and turtles were placed among the viviparous quadrupeds, because they have four legs. Barnacles were placed among shells—among oysters and clams—because they had a solid external covering; and other similar mistakes were made, which have been successively corrected.

The corrections of these mistakes have been made after a certain knowledge of the internal structure of animals had been obtained. And it was found so satisfactory to derive information from the investigation of their internal structure, that soon comparative anatomy and the knowledge of the internal structure of animals became the real foundation of the classifications of the animal kingdom.

It was the result of the brilliant investigations of Cuvier, to show that a natural arrangement of the animal kingdom could be based upon the structure of the beings which were to be classified. It was from such data that arrangements could be produced, according to which all the kinds of animals which were brought together were found to agree in the most essential peculiarities, even when they had not been previously investigated anatomically.

This is one of the promising results of those investigations of Cuvier which made internal structure the foundation of the natural system. But he found at the same time, that otherwise natural groups had the same structure; and that from a knowledge of a few individuals, a great many

facts could be acquired. The knowledge of a few fish, enabled him to compare the whole class of fishes with reptiles; a knowledge of a few reptiles, enabled him to institute extensive comparisons between reptiles and birds; and again, between these and mammalia; and to find that all these animals agree in certain respects. And however many have been examined since,—and three or four times more have been examined than the number which Cuvier had known when he laid out his classification—however many have been studied since, they have all been found to agree in these essential particulars. So that it is now plain, that structure is the principle upon which animals can be most satisfactorily classified. And as I shall often have occasion to refer to this classification, let me at once, in a few words, indicate which great divisions Cuvier introduced into his animal kingdom.

All the animals which I have mentioned, Fishes, Reptiles, Birds, and Mammalia, are combined together, because they have a series of backbones, called vertebræ, by anatomists; and hence the name of vertebrated animals. They agree in the general structure of their brain; they agree in the general arrangement of the fleshy parts, and in the general arrangement of the organs of life—as of the organs of respiration, the heart, the alimentary canal, and so on.

Another group, which was established on the same principle, is that to which we may refer worms, insects, crabs and lobsters—all animals whose bodies are divided into a series of moveable rings,—joints, which surround the body and enclose the soft parts; and which are provided with moveable legs, and in some, even in addition to these legs, also with wings. All these animals have a most remarkable arrangement of the nervous system; there being a series of swellings of nervous substance placed, one in each of the rings, and connected together by double threads; so that the nervous system is all contained in one cavity, not only the general arrangement of parts, but this most important organ of life is also different from that of vertebrates.

The next great group is that of *Mollusca*, containing cuttle-fish, snails, slugs, clams, and oysters,—all those animals which we generally call shell-fish—those which are provided with hard structures—the body being soft and generally surrounded by a great quantity of mucosity; the nervous system consisting simply of a circle surrounding the alimentary tube, with a swelling above the intestine, and another below, from which all the nervous threads arise, which are diffused into all parts of the body.

In these three groups of the animal kingdom, all parts are in pairs, placed on two sides of the longitudinal axis. In all of these there is an anterior and posterior part; two sides, a right side and a left side; and they have a back part and a lower part; they are, in fact, symmetrical.

But there is another group, in which there is a different arrangement. The mouth is in the centre of a circular body; and from this mouth, the organs are placed like rays, diverging in all directions. Here we have no right, and no left side, no anterior and no posterior extremity. The body is star-shaped; and the nervous system has the same general structure, consisting of an horizontal ring around the entrance of the alimentary tube, and has no longer an upper and a lower swelling, as in *Mollusca*.

There have been a few modifications made in the details of this arrangement as proposed by Cuvier. Some of the animals placed among the *mollusca*, were found to belong to the group of *articulata*.—Barnacles are one of this group; a very remarkable family, from the numerous shells around the body. Without knowing certainly, he had placed them among the *mollusca*; but on examination, it was found that their nervous system consisted of swellings, and that their bodies were divided into joints—and an additional evidence was obtained from a knowledge of their young, which were found to resemble, in the earlier stage, much more the crustacea than the *mollusca*; and indeed, that they were crustacea, and assumed this covering only at a later epoch.

However important these anatomical researches have been, it is nevertheless my belief that in this line of investigation we have gained all the important information that we can gain; and that we have to run new tracks in order to improve our natural method,—that we must even give up this fundamental principle, as the ruling principle, if we will make further advance in this science. And my reason is this: The minute investigations which are now making in the anatomy of animals, are bringing forward such differences between them, that we have no principle by which we can appreciate their value. And if we consider every difference in structure as sufficient to separate animals, the time would come when we should form as many groups—as many divisions—as there would be smaller groups in the animal kingdom, as it can be shown that even genera differ anatomically among themselves.

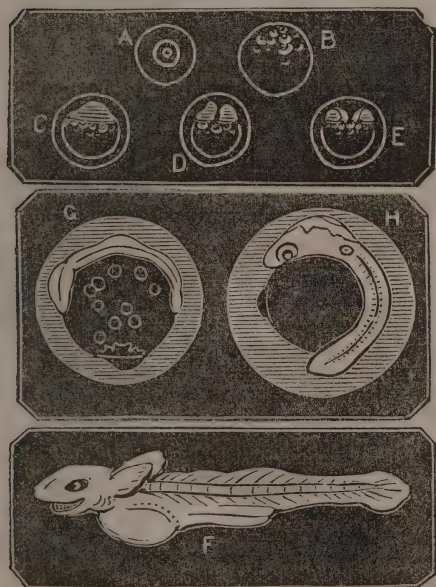
If I am not entirely mistaken, these new investigations, this new information, must be derived from embryological data. It is to the study of young animals—it is to the investigation of the formation of the germ within the egg, that we must appeal for a ruling principle to ascertain the real, natural position of the subdivisions of the minor groups in the animal kingdom. I acknowledge that the great divisions will always stand on the anatomical structure. But the subdivisions of the classes cannot rest upon anatomical investigation; and if I do not fail in my endeavors, I hope to show it to you satisfactorily. This new step is a natural consequence of the natural progress and state of our science.

Investigations have recently been carried on,

more particularly than before, upon the growth of animals within the egg; and some facts have been brought to light which have their bearing on Zoology. Though how these facts have to be applied to the study of classification, has not yet been traced. Embryological investigations have been particularly made with reference to Physiology—that is, with reference to the mode of formation of the various organs which exist in animals, and not with reference to ascertaining their natural relation among themselves.

Another series of investigations which have modified considerably the views which were entertained of the structure of the animal kingdom, are those microscopical researches upon the intimate structure of the tissue of the mass of the body. Of what does the flesh, the bone, the nerve, the various masses of the body, consist? and how have they been gradually formed? has been the object of various microscopical investigations. And again, in this department facts have been brought to light of which we can avail ourselves in investigating the natural relation of animals. On introducing a series of Lectures on Embryology, my object is not to illustrate embryology in the same sense, in the same manner, in which it has generally been traced.

[PLATE I—EGGS OF FISHES.]



I shall not undertake to go back to the beginning of animal life, to attempt to illustrate in what manner individual life is produced, and how, generation after generation, new sets of individuals of each kind are made to succeed each other. I shall simply take the germs as they occur in the egg, to trace the changes they undergo; and by the knowledge of such changes, show that they form such series as agree with the natural series

in the animal kingdom. My object is not merely Embryology; it is Comparative Embryology. And under Comparative Embryology, I mean the comparisons of those phenomena which have been traced in the growth of the different animals, and the different modifications which occur in individual species, throughout the different classes, in their natural gradation, when full grown.

Let me, with a reference to a few diagrams, show what I mean. Here are the various stages of the growth of a fish. See here [A] the egg in the earliest condition. Here is the first indication of something different [B]. Next we see it still further advanced. There are afterwards successive changes taking place, which go on to give rise to an elongated mass, [Plate I, C D E] which swells and elongates more and more till in the anterior portion there is a greater swelling, which finally assumes a more decided change, till there are indications of longitudinal lines, which grow more prominent.

The transverse divisions are introduced until we see a little fish is coming. [Laughter]. From this time it undergoes another series of changes. It resembles more a fish. The head is now distinct. The back bone appears here. It begins to be movable and finally, [F] we have the form of the fish, with the mass of yolk under the abdomen.

Now, embryology traces all these changes from the first formation of an egg to the formation of the germ within the egg; but the germ is not yet formed. We have next to witness the formation of the animal; and afterwards we trace in the primitive egg, the successive changes of the first rudiments—we trace its transformations. We have first its formation in the egg. We trace afterward its transformation through changes of different forms. And it is important to distinguish between these two orders of phenomena—the formation of the germ, and the transformation of the animal into different outlines. The one would be the subject of embryology proper; the other is called the metamorphosis of an animal; and has been particularly studied among insects, where the new being passes through very different and quite distinct forms. For instance, in Butterflies it is first in the form of a caterpillar, as you see here:—[Plate II. fig. A.]

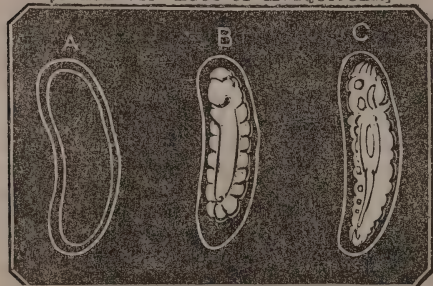
[PLATE II—BUTTERFLIES AND CATERPILLARS.]



Here it is older, [Plate II, fig. B.] It is what we call pupa, but it is only an older caterpillar and not yet fully grown. These are simply stages in one and the same animal; and we have been misled by ideas which we had formed from what the ancients called metamorphosis; we have been allowed to let ourselves think that they were one class of beings transforming themselves into other beings; but they are not. They are all one thing in different stages.

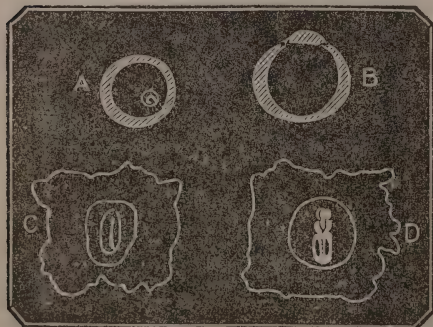
As is the caterpillar, so is the pupa; and so is the perfect animal, the butterfly. The animal remains in the first condition for a certain time, and changes his condition and remains in the second condition a certain time, and finally arrives at its last transformation. And before it can undergo such changes, it had to be formed. And in the changes which the substance of the egg itself undergoes, it is the substance of the egg which gives rise to such a primitive form, and then undergoes metamorphosis.

[PLATE VII—EGGS OF MOSQUITOES.]



This is the egg of a musquito, [Plate VII, fig. A.] And there is the external mass [Fig. B.] making its appearance. After some changes, it becomes divided externally, and when the little worm which is within the egg escapes, it is in the form of a larva. It then undergoes transformations by which it finally assumes its perfect form.

[PLATE VIII—EGGS OF RABBITS.]

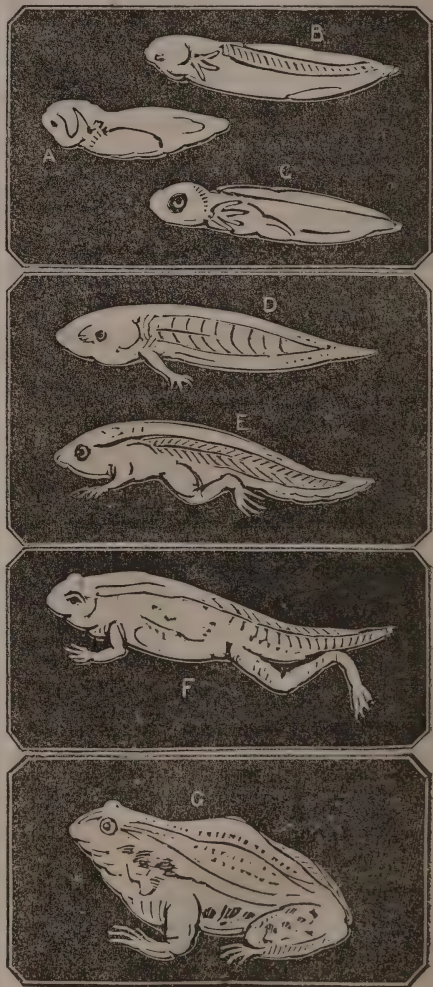


A transformation takes place in all animals. This [Plate VIII, fig. A.] represents the egg of a rabbit. It undergoes similar changes to those in the fish. It gives rise to the prominent mass as seen here, [Fig. B.] This spreads, and there is a

longitudinal line marked beneath, [Fig. C.] And here, [Fig. D.] we have, after certain transformations, an animal with its blood vessels, growing towards the perfect form. And in this way we have the various transformations or metamorphoses take place.

In other animals the metamorphoses are gradual. We see, for instance, the tadpole, from the singular form first seen [Plate III, fig. A.] passing gradually into the form of a frog. But every metamorphosis takes place gradually, not seemingly from one animal to another, but by changes of the same animal to others and other forms.

[PLATE III—FROGS]



Now, it will be the knowledge of this metamorphosis of animals which I intend to make the foundation of a natural system of Zoology. And how that is to be done, I will explain by an example, and refer to the class of reptiles; as I find it is

in that class in which we have the most matured materials for such an investigation. I might have selected a more worthy subject than frogs and salamanders, and perhaps have alluded to the higher animals. But let me say, there is nothing unworthy of our attention in nature. And if we can trace the action of the creative power in these animals which we despise, let us consider that they were made by Him, and if they were worth making, they are worth considering by us.

The class of reptiles as it is now circumscribed, is a very natural one, though it was not always so in the works of natural history. There was a time when crocodiles, lizards, turtles, were not ranked among reptiles, but were placed among quadrupeds, with all the higher animals—all the higher mammalia—and when reptiles were to naturalists only serpents and frogs; and even then they divided those animals into two groups—the creeping snakes in one, and the jumping batrachia in the other.

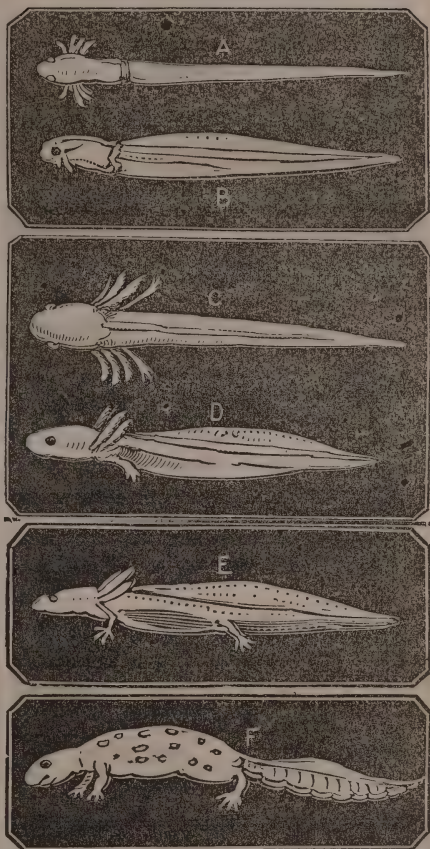
Laurenti, an Austrian naturalist, was the first who described these most carefully, bringing together frogs, lizards, turtle, salamanders, toads, and combining in one natural division all the principal animals which we now refer to it.—But his classification was not much better on that account. He placed in one and the same division, salamanders, and lizards, and crocodiles, which we now know to be widely different; and he did not place in that class another group of animals, which we refer to it the *Cæcilia*. I shall not enter into too many details, for fear I should not finish what I have to say this evening.

Linnæus followed the same example. He brought together turtles, crocodiles, lizards, snakes, frogs and salamanders, but unfortunately left in the same class some fishes, which he combined with the reptiles, owing to some peculiarities of their solid frame. Linnæus also left the salamanders with the lizards, because they had four legs.

Here is one of these animals [Plate IV, fig. F] Brongniart, the celebrated geologist of Paris, studied these animals, and happily threw great light upon the subject, when he showed that reptiles could be divided into four groups—the turtles being one, the lizards another, the snakes a third and the Batrachians, as he called the frogs and salamanders, the fourth and last group. And in this, for the first time, we see salamanders separated from lizards and brought into connexion with frogs and toads. He had noticed that these animals undergo similar changes—that they are equally naked—that they have not the scales which characterize higher reptiles, and he therefore brought them together, but he left out an animal which really belonged to that class. A naked snake called *Cæcilia* by naturalists, was left out and included among the snakes.

I shall use the term Batrachia to designate all those animals which are allied to frogs and salamanders. We have a great variety of these ani-

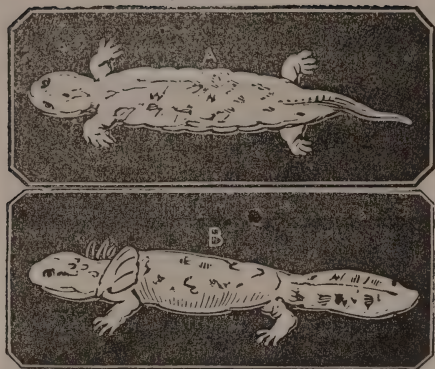
[PLATE IV—SALAMANDERS]



mals. After the publication of the works of Brongniart, Oppel, Dumeril, etc., (who also introduced new views on the subject) they were extensively studied, so that in the museums these animals became more numerous, and it became necessary to introduce some subdivisions among them. Now let me show what sort of animals are referred to this order of Batrachia. And in the first place we have the type of frogs. [Plate III.] Animals which have four fingers in the anterior leg, and five behind. There is no tail to those belonging to this group—we refer to the frog and the tree-toad. There is a web in the finger of the frog; but in the tree toad there is a kind of web, and it is floating. But in the toad the fingers are entirely free.

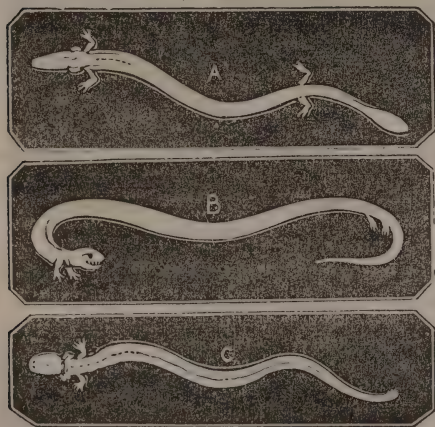
In the salamanders there is a tail. There are four fingers at the termination of the anterior extremity and five at the termination of the posterior extremity. Without the tails, salamanders would be compared with frogs and toads. If their body was somewhat more contracted they would resemble each other very strongly. And indeed, their internal structure is similar. On account of the

[PLATE V.]



presence or absence of a tail, these have been divided into two groups—without a tail and with the tail. The tail is shorter and thicker and the whole body is more contracted. [Plate V. fig. B.] Here are gills which do not exist in any other of this group, gills which exist in the whole life only with fishes; but which here exist simultaneously with lungs in the body. This is called [fig. B] *Menobranchus Maculatus*; and this [fig. A] is called *Menopoma Alleghaniensis*.

[PLATE VI.]



Here are three fingers forward and two backward. [Plate VI fig. A.] This is found in Southern Germany. Here [fig. B] is one with a very minute fin. This is a species which occurs in Georgia. And here is an animal [fig. C] which has anterior legs but no posterior ones, and occurs in our Southern States. There is another type which is not figured, in which there is no tail, no legs, and only a transient and temporary gill. It is the *Cæcilia*—the so called naked snake. The position which is now assigned to these different animals is as follows: As late as 1826, Fitzinger, who has furnished an elaborate dissertation on this class of reptiles, classes at the head of Batrachians the genus *Cæcilia*, still impressed with its

resemblance to the snake. He considered it as allied to the snake and placed it at the head of Batrachians, which are from their structure the lowest type among reptiles. Next he placed the frogs and toads, then the salamanders, and those animals next these, like salamanders [Plate V. fig. B.] This was followed by all following investigators of succeeding years. Cuvier, in his animal kingdom, in 1829, however, made a step backward. He replaced the *Cæcilia* among snakes, though he could not have overlooked the investigations of naturalists who had shown that the want of ribs, the peculiar articulation of the head with the trunk, was much more closely allied to that of frogs than to that of snakes; and the want of movable jaws, again, should have prevented him from confounding the *Cæcilia* with snakes.

He placed the frogs at the head, next the toads, next the salamanders without external gills, and finally the salamanders with external gills. I have given these details on purpose to show that in all these methods there is no principle; and I refer to the leading authors in the natural history of reptiles in order that I may not be taxed with overrating the value of the principle which I am now about to introduce, or of over-rating its influence—its value. Wagler, who is also the author of a system of Herpetology, places at the head, *cæcilia*, next frogs, then toads, next salamanders, and finally, the proteus and menobranchus. Canino followed in a similar track; so did Johannes Miller, of Berlin, who modified it somewhat, placing the naked snake lowest. Next this one, which has no external gills, [Plate VI. fig. B.] and finally this one [Plate V. fig. A.] And above these he places those which have gills, and above the salamanders, the frogs.

Tschudi, who has published a natural classification entirely devoted to this subject—that of Batrachians—places *Menobranchus* lowest. Then he places the naked snake between salamanders and frogs; which he justifies simply from the structure of the head, or at least, gives that as his reason for the arrangement. Now you see that from want of a principle, all these details differ in the various authors. No one is ruled by anything but his impression—his feeling about it. And I think that we can substitute a principle, and we can show that this principle has nothing arbitrary, and is given to us by nature.

Let us trace the metamorphoses of frogs, and there we have the key. What are the changes which frogs and salamanders undergo? In the beginning, for instance, salamanders are animals without legs at all, [Plate IV. fig. A.] with a long tail, and large gills on the side of the head. A change takes place. [Fig. B.] Another change occurs; the gills remaining and growing larger, when an anterior pair of legs appears, and in another stage the gills are reduced [Figs. C. D.] when the second pair of legs appears. [Fig. E.] Here the anterior pair has four fingers, but here [Fig. F.] is a

further change of the same animal, when it loses its gills entirely, and the posterior pair of legs assumes an additional finger, the animal having four fingers forward and five backwards.

What changes does the frog have? Hatched, he is an animal without legs and without gills. [Plate III. Fig. A.] The salamander is hatched with gills, but there is an epoch when it is without gills, and without tail, and without head, and only a fissure on the sides to indicate where the gills will be formed, but not yet external gills. The frog has not yet gills, and not yet a tail distinct from the body. But next, the tail makes its appearance. [Plate III. Fig. B.] when the head separates more distinctly from the mass of the body, and the tail grows longer. [Plate III. Fig. C.] and here [Fig. D.] the tail grows still larger. But in addition to that we have a pair of anterior legs, and the gills have disappeared. Then we have the same growth in the posterior legs [Fig. E.] coming out, though not yet as large as they are here [Fig. F.]. You see that the size of the tail in proportion to the main mass is reduced, and finally the tail disappears entirely, and we have a frog. [Fig. G.]

Here, in these facts we have not only the history of the transformation of salamanders and frogs, but we have a natural system of batrachians, and there is no longer any arbitrary arrangement in our system possible. Every thing is indicated in the metamorphoses of the animals.

Here we have a tailless, and gillless, and footless animal, [Plate III. Fig. A.] Suppose it grows no longer it has the appearance of *Cæcilia*. Next it assumes gills—rudimentary gills, in the condition in which we see the primary growth, with rudimentary legs formed. This stage corresponds to *Siren*. [C.] And here is a second pair of legs formed, [Plate III. Fig. E.] answering to *Proteus*, [A.]. And here we have it shortened, [Fig. F.]—the corresponding animal in its full formation. See Plate V. Fig. A.

Whether or not this one [Plate VI, Fig. B.] will be lower in the scale than this [Fig. C.] we have yet to determine. And all these American species will be examined, which will throw so much more additional light upon this metamorphosis, that there will be no doubt in regard to the position of that animal. The two posterior legs have only four fingers, while the other has five fingers. The tail is shortened, as we see successively, in the frogs and toads. But of the three toads, which is to be placed higher and which lower? That *menobranchus* stands lower than *menopoma* is plain, as in the former the existence of the web is a mere rudi-

mentary condition. The web fingers are observed in all these early stages of growth, and those which have distinct fingers, when fully grown, have them webbed when young. Therefore, we shall see that the frogs are not to be placed higher. And frogs must be lowest, next tree-toads and then toads the highest, because their fingers are finally entirely separated.

And in conclusion, I will say, that in studying the metamorphoses of animals, we may find in the transformations—in the different formations through which they pass, from the first formation up to the full grown condition, a natural scale by which we can measure and estimate the position to ascribe to any animal belonging to this family.

And, undoubtedly, the various genera of this family which I have mentioned, will find their places as soon as all the different metamorphoses of these different animals are known. At present, we know only the transformations of frogs and of salamanders, through the researches of European Naturalists. The metamorphoses of the numerous species of that family which occurs in the United States not having been investigated.

But this agreement of transformation is most remarkable. Nevertheless, we must acknowledge that these perfect animals which occur in different parts of the world in our day, are not copies from metamorphoses from the different stages of the growth of frogs; but they are animals of a peculiar kind, produced in various parts of the world, showing proof that there is one and the same plan ever producing the formation of this whole class, as well in the development of the young from the beginning of their growth to their full grown stage, as in the formation of the different animals which inhabit different parts of the globe.

There is a freedom in the development of this plan, a freedom in which we can see the action of the intelligent Author of all these things.

We read here the intelligent action of the Creator in the production of these animals; and we read more than the intelligent invention of his creation. We read the omnipresence of his action, as his action is developed on all parts of the globe, in the United States, in Europe, in Japan, in South America, and in all the portions of the globe.—And when developed in that way in its actual condition, we see that every one of them, when reproducing its species, passes through these different changes—the higher one, through more of the changes; the lower one, undergoing only the earlier modifications.

LECTURE II.

The object of my first lecture was, to show that after Comparative Anatomy had illustrated the general relations of the animals throughout the animal kingdom, it was possible to ascertain more closely the nearer affinities of the different minor groups, by tracing the relations which exist between full grown animals and the changes which animals of the same family undergo during their earlier stages of growth, from their first formation in the egg to the epoch when they are full grown.

In one instance, I think it has been possible for me to show that the various forms which we observe in the class of reptiles, in that order of reptiles which naturalists call Batrachians, really correspond in their general character, though not in the particular features of their proportions, to those which the higher species of Batrachians present up to the time when they have assumed their higher form. This result shows that the principle exists; though its application in the different classes of the animal kingdom is at present not possible in all its details.

But this result gives also evidence of another important view; that is, that there is really a plan in the animal kingdom; a plan which can be read without any part of the view arising from us, but being taken from nature. We read there the doings of an Intelligence which created those things; and we can read even more than that, in this plan. On dwelling upon another fact, in my Wednesday Afternoon lecture, I showed that this plan is not carried out in one locality, in a few types merely; but that it is worked out all over the surface of our globe; and that, therefore, the result of this investigation shows the Omnipresence of the Creator in his creation.

It becomes now my duty to enter upon a special illustration of the various classes of the animal kingdom, in order to trace, if possible, similar relations between them.

I shall begin with the great group of radiata, the lowest in the animal kingdom. My reason for doing, so is, that the animals belonging to this type are the simplest; and perhaps it will be easier to show here how the egg, with its simple elements, can undergo such changes as to give rise to the formation of an animal; and the changes not being so extensive as they are in higher animals, it will be more readily understood how they are brought about.

The type of radiated animals is divided into three classes: the polypi, or polyps; the jelly-fishes, or medusæ; and the echinoderms, or star-fishes and sea-urchins. These three classes differ in their general structure, and their differences

have been made out by anatomical investigations. They have general relations to each other, by which they belong to the type—to the great group—of radiata. Owing to their simpler structure, the polypi stand lowest; next come the medusæ or jelly-fishes; and among radiata we place the echinoderms highest.

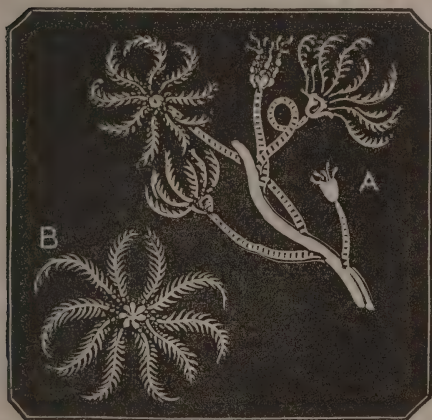
I shall begin with the echinoderms—though perhaps the polypi, from their simpler structure, may answer best the first purpose to which I alluded, and be more easily understood. But there is an objection to my taking up polypi first; it is the fact that naturalists have not agreed as to the subdivision of polypi into families, from the fact that their structure being so simple, it is difficult to estimate the value of the differences which they present; and therefore, these differences have not brought to light a clear gradation of the families. And perhaps there is another difficulty with them to overcome—the fact that individual life is not so distinct among polypi; that several individuals remain combined together to lead a common life; and therefore, we should have to allude to increased difficulties in the estimation of these beings, when investigating the mode by which individual life is established, and by which individuals grow. Those difficulties will be easier understood after we have traced the growth of animals which are really individuals in the proper meaning of the word; that is to say, which grow isolated—which are detached from the parent early in life, and grow separate.

The Medusæ would perhaps answer next; but so singular phenomena have been observed among them that I fear to allude to them at once. We observe, namely among the Medusæ, the singular circumstance of alternate generations; that is, of a progeny which do not resemble the parent—of a second generation which differs from the first, a second generation which returns to the form of the grandparents; and so on successively. And this singular order of succession of individuals of different aspects, makes it difficult to understand their different analogies—to understand the differences by which the two generations differ. Therefore I shall begin with the highest class—with the Echinoderms—where we have, in the successive generations, truly independent individuals, arising from parents similar to their progeny. Moreover, the Echinoderms have been extensively studied, they have been the object of monographic investigations; their genera are well characterised and naturally circumscribed. A great many of these have been found in a fossil state, and these fossil remains will compare with the living types. Such differen-

ces have been found between the fossils and the living ones, that we shall have an opportunity to allude to another relation which exists between these different forms. Those which have existed earliest upon our globe, in the ancient geological epochs, do not indeed resemble those which live now; but they are related to the forms of the Echinoderms of the present day in their earlier stages of growth. And so the class of Echinoderms will afford us the means of investigating all the differences which exist between the animals of that class living now, as compared with their embryonic changes, and also between the changes which the representatives of the same class have undergone from the earliest geological times, up to the time when the order of things which now prevails upon this globe was introduced.

But yet very little was known of the embryology of Echinoderms. Two singular investigations had been made upon this subject, one by Mr. Thompson, of Cork, who had ascertained that the Comatula, a star-fish with pinnate rays, of which you have here a figure [Plate I, fig. B] produces young like this [Plate I, fig. A], resting upon a slender

PLATE I—FIGS A AND B.



der stem, which during their growth cast this stem, become free, and assume finally the appearance of Fig. B.

Next, a Norwegian naturalist, Mr. Sars, traced the changes which the egg of the Star-fish undergoes. Here are the different figures which Sars drew of the young of a small species of Star-fish called *Echinaster Sarsii*, which occurs on the Norwegian coast. It is first a spheroidal mass, which

[PLATE II—SARS' YOUNG STAR-FISHES.]



is said to move free, like Infusoria, when upon one of its surfaces three tubercles are first observed. [Plate II, fig. A].

These tubercles soon become more extensive and run together, forming a figure, similar to a Roman T. [Fig. B].

Here it is in profile, [Fig. C] where the cross of Fig. B. appears like two horns on the upper side. This prominent part next assumes this figure [Fig. D] and seen in profile, it is like the letter E. After this the sphere is divided into five lobes, [Fig. F] with a central one more prominent. Finally, that figure would become more and more flat [Fig. G] its prominent horns which had grown larger, are afterwards reduced, and finally disappear entirely, and an animal similar to a Star-fish is produced.

From these investigations, Sars concluded that the young star-fish was originally a spherical being, swimming free like the infusoria—that it soon assumed a bilateral form, and that this was finally changed to a star form. In this I think Sars has been mistaken, in as far as the bilateral outlines of the young as he represents it, is only the result of a lateral flexion of the peduncle hanging under the centre of the umbrella-shaped little animal.

But in order to show how a simple egg is transformed into an animal so complicated as the star-fish, it is now necessary for me to allude, first, to the structure of Echinoderms in general. It would be otherwise impossible for me to show how the various parts are gradually developed, if I could not refer to the complicated organization of the full grown animal. These details would indeed have very little interest if they were not described in connexion with the complicated structure of the perfect animal.

[PLATE III—GERMS OF STAR-FISHES.]



[PLATE IV—YOUNG STAR-FISHES.]



VERTICAL SECTIONS.



These figures [Plates III and IV] represent the changes which I have observed in a species of Star-fish from Boston harbor, from its first formation in the egg up to its perfect condition; though I have not been able to trace it to the full size to which it grows on these shores. Sars has not been able to ascertain the internal structure of the Star-fish, because the species which he observed was too opaque, and did not allow an investigation of the internal parts. The species which I have compared admitted of such an examination, having more transparent parts, and by a peculiar process of investigation it has been possible to observe the whole internal structure, the specimens being pressed between two glass plates, when placed under the microscope.

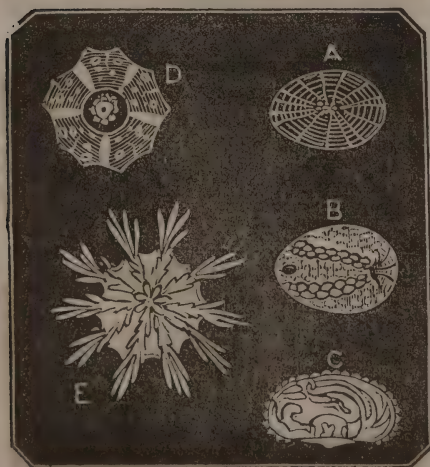
Before I allude to all the details represented in plate III & IV, let me show from these figures how I conceive that the diagrams of Sars [Plate II] though drawn from nature, give an erroneous impression of the animal. It is simply that the peduncle hanging from the centre of the discoid or spherical body being laid flat upon a glass plate, and perhaps pressed it on the glass, for the microscope is bent sideways, and thus it is seen as in these figures. But when seen floating, it will be noticed that this peduncle hangs downward, [Plate III, fig. A, B, C, D].

As a class of animals the Echinoderms agree most remarkably in their structure, though differing most widely in their external forms. We have in the first place elongated forms, somewhat like worms, with a star-shaped extremity, called *Holothuræ*.

[PLATE V—HOLOTHURÆ]

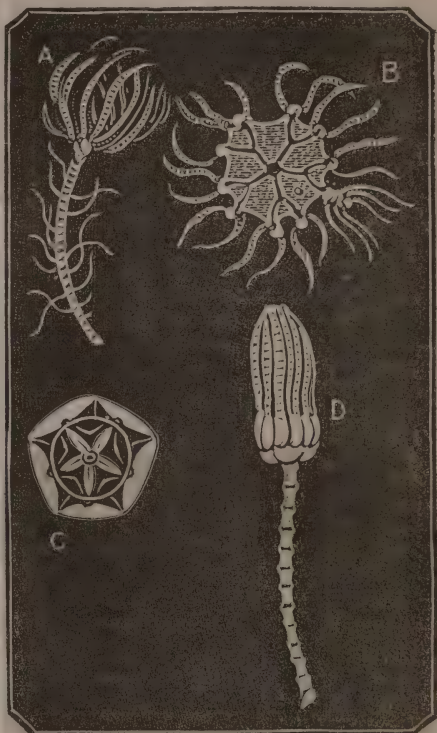


[PLATE VI—ECHINODERMATA]



Here are spherical or spheroidal forms of these animals called Echini or Sea-Urchins, [Plate VI] and finally star-shaped ones, called star-fishes, and among which there are free ones, those which rest on a stem, like lilies, [Plate VII, fig. A, D.]

PLATE VII—STAR-FISHES—CRINOIDS]



These various animals are so widely different that it seems scarcely possible to find a fundamental plan of structure and a uniform arrangement of parts in all of them. Yet it is so. Conceive for a moment that the fundamental form is a spherical one. If the sphere is extensively elongated, we have the form of the *Holothuræ*, Plate V.; the spheroid form itself may be more or less ovate [Plate VI.] or angular; or if the corners of these be drawn out, we have a real star-fish. In the centre of some of the circular ones there are plates or prominent knobs on the summit, [Plate I. fig. B.] which may form a kind of peduncle above.—Now it is easy to conceive that these growing longer will appear in the shape of a longer or shorter stem upon which the animal will move, [Plate VI. fig. A D] balancing itself. So that from these polypi-like forms up to the worm-like forms we have gradual transitions.

As the highest among the radiata the echinoderms are more complicated in their structure.—Their external coverings are already more distinct than in any other. In the polypi the skin is closely attached to the fleshy mass of the body. Here

we have an envelope which is entirely separated from the internal organs, forming a covering, which is either hard, leathery and strong, or a firm coat, consisting of numerous calcareous plates united together, or connected together in a movable way. These external coverings are not like a shell resting on the soft parts, but they form intricate connections with all the different systems of organs, although these be distinctly separated from the external envelope. For this purpose they are pierced by numerous holes of various kinds. Indeed the connexion of this external covering with the internal frame is manifold. The mouth again, which is always toward the centre of the animal, is also only an opening in the middle of the disk, and upon its edge are various movable parts performing the functions either of teeth or tentacles, by which the food is seized. In another position, frequently opposite the mouth, there are other apertures by which the ovaries discharge the eggs, and little holes in which eye-like organs are placed. The organs of respiration which admit water from outside are either in the general cavity of the body, or situated more externally, round the mouth, or on the sides of the animal.

There is in these lower animals a closer connexion between their inner cavity and the surrounding media than in any of the higher classes. The water rushes freely into the body through innumerable pores and fills its cavity. Some of these tubes assume a very peculiar arrangement in echinoderms, and become simultaneously subservient to locomotion. As this apparatus is one of the first to appear in the young, let me allude to its structure as we observe it in the starfish. Here are the different rays [Plate VIII. fig. B] projecting from the centre. There is a sac projecting in the main cavity of the body—a stomach—and from this stomach we have appendages projecting into the rays, to which a kind of liver is annexed, and filling for the most part the cavity of the rays.

[PLATE VIII.]



In the figures [Plate IV, figs. E, F] in which the starfish is cut vertically, the sacks extending from the stomach, with the liver attached to them, are seen in their natural position. The nervous sys-

tem forms a ring all around the walls of the opening leading to the stomach; and there are nervous threads arising from this central ring to each of the rays, and extending in five different directions to their extremity. And at the end of each ray there is a colored dot protected by a hard shield. This colored dot has been ascertained to resemble the lowest form of eyes.

The solid frame which protects the whole animal consists of various little plates. [Plate VIII.]

They are numerous on each side of the rays, and there is another one at the end, and it is below this last one that the eye is placed. Those solid plates on the two sides unite with many others placed transversely to form the lower surface, and alternating with each other. Between these transverse plates are the holes for the tubes mentioned before. At the end is the odd plate.

These tubes are seen here hanging down [Plate IV. fig. E.]. They communicate inside with small vesicles, to which minute tubes lead, communicating with larger tubes, which extend along all the rays, one for each ray, arising from a circular tube, which surrounds the opening of the stomach. And the whole apparatus communicates with another tube, which penetrates from the dorsal surface downwards, having its opening shut by a perforated plate called the madreporic body, which in starfishes is always seen in the angle between two of the rays; so that we have here an hydraulic apparatus of a very complicated nature. Indeed, from the upper surface of the starfish, where the little sieve through which the water penetrates is situated, there is an uninterrupted communication to the circular tube around the mouth, from which five tubes branch out, one to each of the five rays; and from these, they open to the vesicles, and thence penetrate into the tubes. But the water can enter the vesicles through the external lower tubes, fill the circular tubes, and pass out the other way through the madreporic body. This apparatus is subservient to various functions. In the first place, the lower tubes serve as a walking apparatus; the animal being fixed and creeping by the contraction of the tubes, and again water being introduced into the vesicles upon which are spread numerous little blood vessels, and the water acting upon these blood vessels modifies the blood, and gives it the peculiar character necessary to perform its functions, constituting a peculiar kind of respiratory system. The minute holes spread over the whole surface of the body, serve simply to fill the general cavity with water.

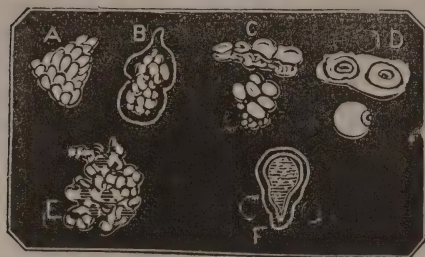
The heart is placed along the calcareous tube which arises from the madreporic body, and the blood vessels form circular rings around the entrance of the stomach, from which and to which the radiating arteries and veins move.

Another apparatus which is very voluminous in starfishes is the ovary.

There is such an organ in each ray, concealed between the appendages of the stomach, which open

upon the upper surface with little holes through which the eggs escape. The ovary itself is a granular organ, of which several figures in various stages of development are here seen.

[PLATE IX—OVARIES OF STAR-FISH.]



Such is the structure of the Echinoderms, the stomach forming a simple cavity, without any other outlet except the mouth. In some the alimentary tube is more complicated. In the Echini or Sea-Urchins [Plate VI] there is an alimentary tube forming several evolutions, and opening upwards. The ovaries form more peculiar masses than in the star-fishes. The mouth is also protected in most Echini by a complicated set of jaws and teeth. In Holothuræ the whole system of organs assumes a more bipartite arrangement.

In the process which gives rise to the formation of new individuals, the first step consists in the accumulation of more or less consistent matter of a somewhat opaque or yellowish appearance, and of a granulated texture which divides soon into small spherical masses. This takes place in the ovary.—This mass, at first homogeneous, assumes soon the aspect of little bunches, which soon grow more and more isolated, and then assume around them a peculiar membrane, and there are eggs. Eggs in their simplest condition are microscopical spheres of a homogeneous mass, called yolk, and surrounded by a simple membrane, called the yolk membrane. [Plate IX C.] However different in its aspect in different animals, this mass is called yolk, throughout the animal kingdom, from the fact that this name has been applied to the part which corresponds to this structure in the hen's egg.

The primitive egg is always microscopical, and its contents homogeneous; but this substance soon becomes granular. It is so small as to escape the observation of the naked eye. And there is another little sphere formed within, which is called the germinative vesicle, containing another little vesicle, which is called the germinative dot. [Plate IX fig. D.] Under a powerful microscope the granules of the yolk itself appear also like little cells.—There are little spherical masses, and they contain even in their turn other little dots.

Plate IX shows the various degrees of the growth of such eggs, of which there are more or less developed ones in the same ovary; assuming first their regular form [Fig. A], and then a transparent space appearing in the interior [Fig. B]; next the

germinative vesicle becomes more distinct [Fig. C], and [Fig. D] the germinative dot is now distinctly seen. The whole mass of yolk, which has grown considerably; consists here of cells, which have been formed by the expansion of its granules. Through this growth of cells within cells, and of granules growing into cells, there is finally a germ formed. That which we call yolk in the beginning, is finally a spherical germ, which will escape from its envelope. We have here [Fig. E] the ovary of a star-fish, from which some germs have escaped, and here is the figure of such a germ already hatched, highly magnified [Fig. F]. The ovary of sea urchins, have all the same structure, and vary only in their size and proportions. Now a curious observation which I have had an opportunity to make, is, that the eggs after they are laid are taken up by the star-fish, and kept between its tubes, below the mouth. The star-fish bends itself around them, surrounds the eggs with its suckers, and moves about with them. When the eggs had been removed to some distance from the animal, it went towards them and took them up again, and moved off with them, showing that these animals, so low in structure, and apparently deprived of all instinct, really have so much instinct as to watch over their young.

Now these eggs which are thus kept there, and protected by the mother, will escape. These germs I have been able to trace from the lowest possible condition, where they resemble ovarian eggs. At no epoch did I see this new born animal living free, and swimming like Infusoria, as is said to be the case by Sars.

Soon, however, the external crust of the germ becomes more transparent, consisting of somewhat looser and larger granules, and the internal mass assumes a color a little darker, so that two layers are distinct, between which there is another one, which becomes also gradually more and more distinct. On one side of the germ there is now a protuberance forming, and the prominent portion separates more and more from the spherical mass, [Plate IX, F] the difference in substance of its layers growing more and more distinct. The prominent portion, which is the lower part of the little animal, becomes more and more elongated and assumes more and more the form of a peduncle. Often there are several grouped together, and attached by this appendage to the empty egg cases; they would even form bunches remaining thus attached till they are far advanced in their growth. At this period, however, there is not yet any organ formed as you will notice on comparing Fig. F of Plate IX. with those of Plate IV. p. 13. Only changes of substance have taken place. But now we begin to see little swellings in five points on the sides; the spherical portion of the germ has also grown considerably, and has been flattened by lateral dilatation.

The little animal has grown to a more hemispherical shape; and from that time there is an up-

per and lower surface to this umbrella-like disk; [Plate III, fig. C] and there is a tubular part and a swollen portion to the peduncle. As soon as the peripheric part of the umbrella begins to spread, we observe five little tubercles forming underneath; and into these tubercles we see that the peculiar aspect of the middle one extends. Soon there will be other prominent swellings forming; but two to each of the former ones; and next, two more, as seen in Plate IV, fig. A, in which the peduncle is represented from below projected upon the centre of the disc. While this is going on, calcareous nets are formed by the accumulation of crystals in the cells of the germ. At first there are little isolated crystals formed as nuclei in the cells; and then several close together will unite and form a little irregular mass, and they will combine so as to constitute a network of solid substance arranged very regularly. They aggregate first about the prominent tubercles of the lower surface, corresponding in position to the five primitive ones [Plate IV, fig. B, page 13].

Now the points in which these calcareous deposits take place are symmetrically arranged [Plate IV, fig. B, p. 13]. Next, five alternating with these arise in the intervening spaces, [Plate IV, B, p. 13] and another is formed in the centre of the disc.

All these networks are, however, not formed in the same plane of the animal; those arranged in fives being deposited below, and the middle one above the central mass of yolk in the periferic layer of the germ.

At this period, the peripheric tubercles of the lower surface become colored in their centre and the external calcareous networks spread over them. The red spots of the tubercles are now very conspicuous. When examined under a high magnifying power they appear like little heaps of colored dots, and these are so many cells with colored nuclei. As peculiar organs, they answer to the rudimentary eyes of the perfect star-fishes.

The calcareous nets which were at first only ten in number, become now gradually more and more numerous, marking out more and more distinctly the rays of the little star-fish which are thus forming, new being interposed in pairs between those already existing, and small spines projecting from the older ones. (Plate X., A.)

The tubercles of the lower surface, which alternate with them, growing more prominent and elongated, are finally transformed into suckers, as I will call them, or the so called ambulacral tubes, [Plate IV, fig. C.] With the addition of new calcareous nets they also become more numerous and form finally rows of tentacles, D, E, F. Other changes have also taken place. The cells within the peduncle have undergone changes. Some have become movable, and a kind of circulation is going on in them. The internal space along each ray has become more transparent; the ambulacral tubes have become hollow, and from that time there seems to be a communication between

the external water and the internal structure. What remains of the yolk is more distinctly circumscribed in the centre of the animal, extending as a star-shaped disc into the rays. The radial portion becomes finally distinct from the central one, and we have at last an internal cavity, which is the stomach, from which the coecal appendages of the rays, with their liver-like organ, will be developed—[Plate IV, fig. E. p. 13]. The peduncle is reduced to a mere vesicle; a hole is formed in the centre of the lower surface, the mouth, around which a circular thread becomes visible, answering to the nervous system, and from which other threads extend towards the extremity of the rays, being the radiating nerves which establish a connection between the peripheral colored spots, which are the eyes, and the central nervous system which encircles the mouth. Before, the young star-fish had thus assumed a life of about one line in diameter; it has now assumed the form and structure of the perfect animal. To this growth there is one point of peculiar interest—I mean the correspondence between the development of the calcareous net works [Pl. IV, fig. B, p. 13, and Pl. X, fig. A.] and the arrangement of the solid plates in Crinoids—[Pl. I, fig. A, p. 13, Pl. VII, fig. A, D p. 14, and Plate X, fig. B.]

[PLATE X.]



But I see that the time has past, and I am obliged to conclude. Let me only add a few remarks before I close. The mode of growth in the star-fishes as I have illustrated it, does not agree with observations which have been recently made by other investigators. Von Baer, Johannes Muller, and several other investigators, have traced the growth of these animals recently. But they have traced them at another epoch than the development which I have observed here [Pl. III p. 13]; and it is now probable that in the Echinoderms, also, there are two modes of reproduction during which the growth of the germ is not identical, as in the animals reproducing by alternate generations. It was during summer that the investigators just mentioned made their observations, and they found that all their germs were surrounded with a most remarkable external frame-work, whilst mine, which are entirely destitute of such envelopes, were observed growing during winter, at a season when animals in general do not reproduce themselves.

However, it is remarkable how many of the low-

er types produce their young during winter. But on considering what may be the cause of their eggs being deposited at this season, we can suppose it is owing to the fact, that during this epoch the water is less changeable in its temperature and will admit of a more uniform growth of animal life than during the spring and summer. All animals of low temperature or whose temperature is deeply influenced by the surrounding medium, in opposition to the higher organized ones, seem indeed to develop more naturally during the cold period of the winter, when the possible changes are only slight, undulating about the freezing point, from about the temperature of the greatest density of water to that of the freezing point it-

self, that is between 32° and 36° . The limits of variation of the temperature of water being so very slight under such circumstances, we can conceive that these low animals are more likely to develop regularly than under the changing influences of spring and summer; when along the shores the influences are extremely variable and might kill so delicate animals which have no means to maintain a temperature of their own.

In my next lecture, I shall compare these embryonic changes with the perfect state of the various Echinoderms of the present creation, and with the perfect state of the numerous fossils of this class which have been discovered by geologists in the successive deposits of former ages.

LECTURE III.

I have shown, in one instance, the development of the star-fishes, as observed on these shores during winter. It was mentioned, that from a spherical form there was gradually a flattened disk, a hanging peduncle, developed, out of which afterwards arose a pentagonal form, which was finally changed into a regular star-fish, with the structure of the full grown animals of that class. These changes have been traced from the beginning of the formation of the germ in the egg, when they are protected by the mother who takes care of them, carrying them about. At no period of this development were the young star-fishes observed swimming free. There can, however, scarcely be any doubt that the young observed on the Norwegian shore were free. The observations of Sars can the less be doubted in that point, as similar moving animals, which were afterwards ascertained to have been the star-fish and other Echinoderms, have been discovered by the investigations of Professor Johannes Muller, of Berlin. This minute and learned investigator described, several years ago, a small animal as a new type in the animal kingdom, which he could not refer to any class, nor to any family. It was a paradoxicon by its form and its peculiarities, and he called it *Pluteus Paradoxus*. It is a transparent mass, supported by several diverging sticks, surrounding an internal cavity (Pl. XII, A) and moving free upon the surface of the water. I have not dared to have them shaded in my diagrams, in order to increase the distinctness of the forms; and only give these slight outlines as they are figured by Muller. In this condition, that animal is bi-lateral as seen from

above. At the two extremities of the longitudinal axis, are two appendages; these appendages are the stems which project laterally in Figs. A and B, pl. XII., they being the anterior and posterior ends of the longitudinal axis. Between these, you see one shorter pair on one side, and on the other side another pair, which hang lower down, [Pl. XII., figs. A. B.] These two pairs of appendages are indeed not equal in length. One pair on one of the sides hangs lower down than the other pair. Between those six supports, united by a gelatinous solid mass, there is an inner cavity, as seen in the figures quoted. The side of the longer ends has lateral projections, so that, in fact, there are eight prominent sticks diverging from the summit of this curious being. No further structure was observed in the first year by Mr. Muller. He only ascertained they moved free in all directions, sometimes rising forwards and sometimes revolving in different directions.

These movements were performed by vibratory cilia, which are minute fringes extending all around the edges of the frame, and which are also grouped on the summit of the animal. These fringes are microscopic. They form a swollen edge round the whole of these dentations, extending all round the edge of these stems. (Plate XII, fig. B.) What this being was, could not be ascertained. It had been observed in the Northern Sea, in thousands and thousands, and could not be referred to its proper class. Whether it was to be considered a medusa or a polyp, or whether it was the germ of some other animal, could not be ascertained.

[PLATE XII—SARS' YOUNG OPHIURA.]

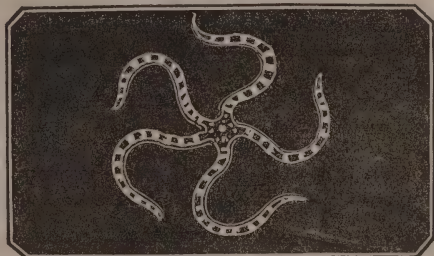


The same observer afterwards found, that within this curious frame there was forming a sack, with an external opening hanging down between the longer lateral sticks. (Plate XII, fig. A.) He describes the opening, (Plate XII, fig. B), as a mouth, the tube above as an œsophagus or alimentary canal emptying into a sack, which he calls a stomach. (Plate XII, fig. A.) The mouth hangs here lowest, the tube above being an œsophagus, and the sack in the centre a kind of stomach. The changes which gradually take place in this animal, and which are represented, Plate XII, from A to F, were noticed, not by tracing one and the same individual, but by comparing the differences between those which were successively fished up from time to time, as it was impossible to trace for a long time the same animal, owing to the fact of their dying away very rapidly.—Comparing various individuals, Muller ascertained that on the sides of the inner sac or stomach, there were little processes or caecal appendages arising (Plate XII, fig. B) from the side, which grew out of two sides of that cavity which he considered, as a stomach; and these appendages growing more numerous, would form finally a bunch in the centre, (Plate XII, fig. C) consisting of about a dozen of such rounded masses distinctly developed from the sides of the stomach. Next there would be (Plate XII, fig. D) a regular arrangement of the growing protuberances arising from five definite points, two and two, projecting more than the oth-

ers from each of these points, and from that time, an indication of the starfish, forming within this curious stage, is clearly noticed.

A regular star-fish has five beginning rays, enclosed between those stems, developed from that hollow organ which in the beginning is the simple sack in its interior, with a wide opening on one end, which gradually disappears in the new animal. At this epoch the young animal has no opening at all; what was first considered as a mouth is shut up (Plate XII. fig. C). After a certain time, however, upon one of the surfaces will be found a new opening, (Plate XII fig. E). The rays are advancing, growing longer by the addition of some new divisions in the mass; and growing larger and longer, the rays would become soon very prominent, and suckers like those of the little star-fishes which I have described, would come out, when a real mouth is seen in the centre, and no indication as to what has become of the curious tube first considered as an œsophagus, (Fig. B). The surrounding transparent frame has been reduced to a few processes, to a few appendages on the dorsal surface of the animal, (Fig. E). They are afterwards still further reduced, only a few remaining appended to the dorsal surface; and at last we have an animal entirely deprived of such appendage, (Plate XII. fig. F). Out of such an envelope will finally grow an ophiura, (Plate XVI.)

[PLATE XVI—OPHIURA.]



an animal in which there is no indication of dorsal appendages, a regular star-fish, with slender cylindrical arms. It is easy to see how the central mass is transformed into the star-fish, from the period (Plate XII. fig. C) when the inner pouch has been transformed into a spherical mass of globules. But the whole series of changes can scarcely be reconciled to what I have observed in the common star-fish of these shores. Perhaps there is some resemblance between the sac of yolk of the star-fish with its peduncle below, (Pl. III fig. A. p. 13.) and the so-called stomach œsophagus and mouth of the ophiura, (Plate XII. A B). Perhaps instead of being a stomach with an œsophagus and mouth, this inner mass is to be considered as a yolk with a peduncle. But whether it be so or not, the difference is nevertheless striking. The young ophiura, when forming, is here (Plate XII) surrounded by a peculiar frame, of which there is not any indication in my star-fish, (Pl. IV. fig. C, p. 13).

Now I have been able to trace the eggs of an *Ophiura* which lived on this shore, and they, as well as the young star-fishes were free animals; and also were observed during winter

The question is now, whether there are not among Echinoderms, as among other low animals, —though the fact has not been traced by direct observations—phenomena similar to what has been observed among Jelly-fishes, where alternate generations take place,—where animals of a peculiar character are produced in one generation, from which spring animals of another character, and generation after generation alternately, the primitive types are reproduced.

That these must be some phenomenon of that kind I can scarcely doubt, when I see other animals indicating a similar change, which has been also observed by Johannes Muller, during summer.

Here is a frame similar to that of the little ophiura, containing within also a more opaque body, with an opening below considered as a mouth, and a connecting tube.

The external frame, also formed of a solid, gelatinous mass, in the interior of which there are calcareous nets, and on the edges of which there are again vibratory cilia all around these stems (Plate XI, fig. A). And there are several groups of these vibratory cilia in the form of crescent-shaped epaulettes on the four corners of the animal. Here is a figure of the same, (Plate XI, fig. B,) seen from above. We have in this being, the same arching appendages which were noticed in Plate XII; but instead of giving rise in their connection to a projecting centre, they form a more rounded vault, from which the elongated sticks hang down, diverging somewhat. From the four corners, however, hang down the four longest of these arms, and over the arms of the corners are the fringed epaulettes; and from one side two equally developed, between which the mouth opens, an œsophagus and stomach occurring in the centre, as in the young *Ophiura*. After the interior mass has undergone some changes, you see, however, a very curious difference, which distinguishes at once this animal from the other; a disc, which is observed upon that spherical mass, namely, (Plate XI, fig. B) the mouth—as it is called by Muller—still hanging underneath, as seen in another figure at the same stage of growth, but viewed in profile (Plate XI, fig. C), where the spherical mass with its lower tube is placed vertically, and where that new disc formed upon its surface is placed obliquely on one side of the upper portion. This disc has at this period five somewhat prominent tubercles upon its surface, as is seen here (Plate XI, figs. C and B), which will become more developed (Plate XI, figure D) The disc will grow larger over what was formerly the main mass, the appendages will be somewhat reduced in their length, and also in the development of their vibrating cilia. And from that time in addition to this, the five tubercles will be elongated into five tubes or suckers, (Plate XI, fig. E.)

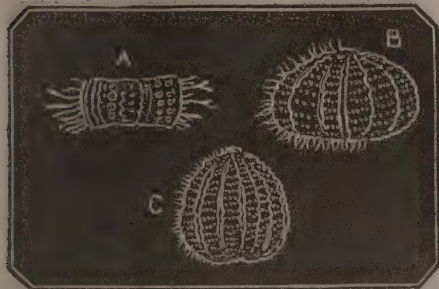
[PLATE XI—YOUNG SEA URCHINS.]



and there will be spines coming out between them, the œsophagus and mouth being reduced and finally disappearing. At this period, the young animal consists, therefore, of a circular disc upon a spheroidal body, with elongated suckers coming out of its edge, with spines between them; but the suckers, instead of being in pairs, as they are in the *Ophiura*, are only five in number (Plate XI, fig. F.); the main mass of the primitive sphere forms still a spherical body under the shield, the shield itself bending over the spherical mass (Plate XI, fig. F). This disappears, however, more and more, and at last there is a little flattened, sea-urchin-like animal produced, with at first five suckers, next with ten, (Plate XI, fig. G.) with large spines alternating with them, the greater portion of the spherical body remaining, nevertheless, soft, as there are not

yet any calcareous plates to support the isolated spines, which rest only upon loose, calcareous nets similar to those of the star-fish when first developed. With these changes in the main body, the external frame is gradually reduced, and finally entirely lost. In this condition of the new animal, when deprived of its transparent envelope (Plate XI. fig. G.) it is easy to recognise a young sea-urchin, a young animal of which this figure, (Plate XIII. fig. B.)—represents the animal in its perfect condition.

[PLATE XIII.—SEA URCHINS.]



Muller has had an opportunity of tracing several other larvæ of the same kind. In one of them there are appendages above as well as below, resembling otherwise the first state of the Ophiura; in another, similar in form to Plate XI., in which there are, however, no crescent-shaped, vibrating epaulettes; in another still, there are two such crescents only; and in all of them there are hollow spheres, with elongated tubes, and a seeming mouth beneath; and all of them are transformed into echini-like animals.

All these observations leave no doubt as to the fact that certain embryonic echinoderms, observed during summer, are protected by an external, complicated frame work, which has not been noticed in those observed during winter. In addition to this, I may mention that this external envelope resembles very much the transparent body of some jelly fishes, the *Beroë* for instance, which are also provided with vibratory cilia, arranged in a peculiar manner, and which move freely in the water. And if we compare this curious condition of the young Echini, with what is known of the growth of medusæ, where a simple egg will divide into several masses to give rise to several individuals we cannot be surprised that there are in the Echini also, similar phenomena; and that a body, entirely different from the animal in its full grown condition, is developed, to nurse, as it were, the perfect animal, and not to acquire in itself any peculiar, prominent, final form. These phenomena of alternate generation I shall illustrate more fully in the next lecture. I merely allude to them now, in order to suggest the probability of alternate summer and winter generations in echinoderms, differing from each other in the same manner as ordinary alternate generations are known to differ.

The young Ophiura, the young Star-fish and the young Echini, have not yet been traced through all their changes up to full grown animals. It was the condition of their growth figured in these various diagrams, respecting which investigations have been instituted; but the further investigation was interrupted by the circumstances. But on collecting along the shores small animals of those species, and forming series of individuals from the smallest size up to this perfect condition, the investigation of their growth and the changes which they undergo, can be made out as completely as if made upon one and the same animal during its real growth. Indeed, most of the changes noticed in the above described larvæ have not been observed upon one and the same individual, but by comparing many individuals of the same kind in their various stages of growth.

Now what are the changes which take place in the further growth of the star-fishes, and of the sea-urchins? In the star-fishes, as they are figured here (Plate IV) the number of calcareous plates is still very small. Only those which surround the mouth, five in number, have acquired a certain size, with those which protect the extremity of the rays, also five in number, and which are also considerably developed; small ones in addition, are successively forming in pairs in the intervening spaces, (Plate IV, fig. C) between which suckers come out. Gradually more and more are developed, the animal pushing in this way the primitive and terminal plates of the rays further outwards.

It is therefore by the further intercalation of new plates between the terminal and the oral ones, that the rays are elongated, and they may grow to a very prominent form, as we have here, [Plate XIII, fig. A.] By varying proportions of their plates, the rays, however, may grow to form very different outlines of these animals, as may be ascertained by comparing their arrangement in different genera of the family.

In the Echini the growth is more difficult to understand. How is it that the circular body can grow larger by the addition of new plates? In order to understand that, let me mention the facts which I have been able to trace with reference to their growth. If we have here an Echinus of a certain size, we will observe that its plates are arranged in two different kinds of rows, [Plate XIII, fig. C.] You see these rows alternate with each other, (Fig. B), and here again, (Fig. A), very narrow rows, alternating with much broader ones. The vertical rows of plates leave a circular hole above, which is closed by plates of another character. And below another hole, which is closed by plates of another character, but the sphere itself consists of plates of two characters, narrower ones, which have holes in themselves, and broader ones, which have no holes, but upon which we observe more prominent tubercles, to which the spines are attached—moveable spines, of which

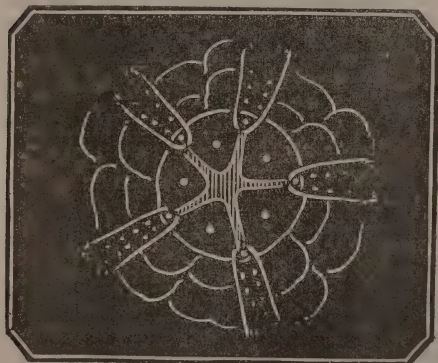
there are as many large ones as there are large plates. The first of these plates, which are solidified in Sea-Urchins, are those which surround the mouth, and which form the outline of that opening which is closed by a membrane, and in the centre of which we really find the mouth in the perfect animal. Above is formed the upper disc, consisting chiefly of the plates, alternately larger and smaller, through five of which the ovaries are discharged, minute eyes being placed in the five others.

The new plates of the sphere are gradually formed above the older ones, around the mouth, and wherever additional plates are developed, they arise higher and higher. In this way we see that the young sea-urchins—the young Echini—are growing larger by the addition of plates between those of the upper disc and those which surround the mouth.

But what are those plates of the upper disc? The five smaller contain the eyes and stand above the rows with pierced plates; the five larger ones give passage to the ovaries and stand above the rows with imperforated plates.

Now in star-fishes we have similar eyes, colored dots, at the extremity of the rays, (Plate IV. fig. A) The plates which protect them (Plate IV. fig. B) correspond therefore to the smaller perforated plates, of the upper disc of Echini, (Plate XVIII.) and the ovarian plates correspond to the angles between the rays of star-fishes.

(Plate XVIII.—SUPERIOR DISC OF SEA URCHINS.)



It is therefore no exaggeration when we say that a star fish is a sphere stretched into a pentagonal shape, and in which the eyes are carried out into the rays; as there are holes opening between the rays in their angles where the ovaries open. In this, as well as in every other respect, the analogy is most complete. Vice versa, we may say, that Echini are swollen or spherical star-fishes, with reduced rays; and Holothuridæ animals of the same structure drawn out into a worm-like tabular form. It is really of some importance to be able to trace this comparison in detail, as it will now at once enable us to show that the analogy of the various embryonic forms with the perfect animals is made out sufficiently to afford the means of appreciating

their relative positions in a natural system, by the analogies which exist between the full grown animals of this class and the changes which they undergo in their formation. Not only are the plates increasing and the body enlarging, but also its form is assuming peculiar modifications. From these pentagonal forms it is transformed into a regular star. The Sea-urchin with a flat disc, as we have it here (Plate XI fig. G.) is transformed into a spherical body, seen here. (Plate XIII fig. B.)

[PLATE VIII.—STAR FISHES]



The star-fish is also gradually transformed from its outlines in Plate IV, into the perfect animal, (Plate VIII.) It now becomes an important point to be able to ascertain to what peculiar forms of Sea-urchin these embryos belong, as we have among the living ones some with the flattened disks, others with a spherical form, and others with more prominent elongated forms. Let us see what sort of living forms we have among Sea-urchins. There are some in which large plates alternate with very small ones (Plate XIII fig. A) which are called *Cidaris*. There are others, in which the plates are more numerous, in which the rows of holes are broader (Fig. B.) and in which the spines are small, *Echinus*. There are others in which we have plates still more numerous, (Fig. C) the body more conical, the rows of holes being still larger, and the spines reduced almost to little heads, *Holopneustes*. On the shores of the Northern Sea, where the above described larvæ of Sea-Urchins were observed, there is no Echinoderm found belonging to the genus *Cidaris*. Nevertheless, you will notice that that young Sea-urchin of Plate XI fig. G. has remarkably large spines, equalling nearly the whole diameter of the animal, although in its perfect condition it will have proportionally small ones. From that very fact we can conclude that the *Cidaris* stands lower than the *Echinus*; though it is usually considered a more elegant and higher form.—This conclusion must be granted at once, when we consider the great disproportion in the size of the spines in *Cidaris*, and the large plates for the spines resembling the embryonic form of the *Echinus*, that the genus *Cidaris* ranks lower than *Echinus*.

In *Holopneustes*, (Plate XIII, fig. C,) in which the rows of holes are wider still than in *Echinus*,

approximating thus to Holothuræ, and the body more elongated. We have really a still higher degree of development.

In the general classification of these animals, I showed that the tubular form is the highest, as is seen among the Holothuriæ (Plates XIV and V).

[PLATE XIV—HOLOTHURIA.]

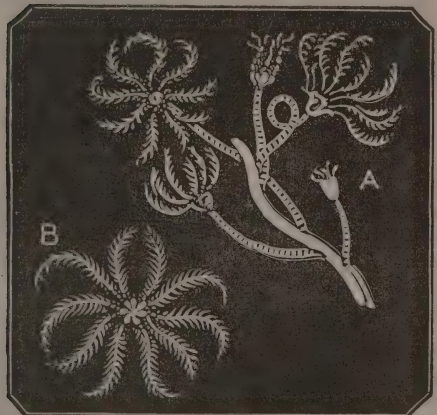


(PLATE V—HOLOTHURIA.)



I might have shown these animals to remind you of what are the species on these shores. Here is the common Five finger (Plate VIII, fig. A), and here is the common Sea-urchin (Plate XIII, fig B) a spherical body covered with spines, which may assist us in comparing, better than simple diagrams, these animals with their embryonic states, as illustrated before.

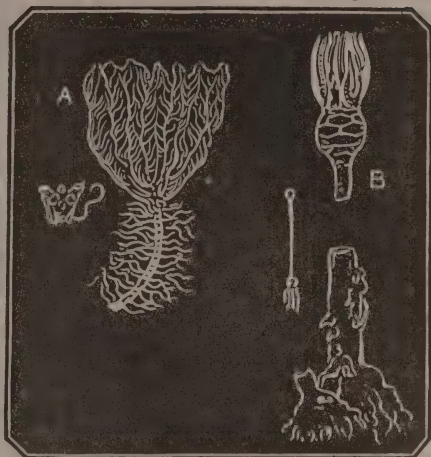
[PLATE I—COMATULA.]



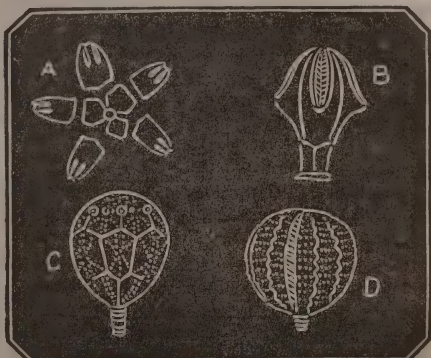
Let us now also compare these embryonic forms with the fossils of different geological epochs. How the young Comatula (Plate I) casts off the stem, I have already mentioned; but if we consider its embryonic form, it will compare most remarkably with the fossils figured here (Plate XV). In other instances, however, the fossil Crinoids do not even resemble the young of those of our present epoch, but belong altogether to peculiar types, as figured here (Plate XVII).

I have been able to bring here a natural specimen of one of these lily-like animals, in a most

[PLATE XV—FOSSIL CRINOIDS.]



[PLATE XVII—FOSSIL CRINOIDS.]



perfect state of preservation, resting upon its stem, which is composed of innumerable plates articulating together. It is a *Tentacrinus*, from Wurttemberg, in Germany. The principal portion of the animal, which is called its crown, divides into five distinct rays, which are flattened down upon the slab of stone upon which it rests, but so well preserved that every one of the ramifications can be distinguished, and the connexion of these branches upon the crown below are very distinct. (The Prof. here showed a most splendid fossil, which excited great interest among the audience. Those interested in this branch of natural history will find the subject carefully investigated in Agassiz and Gould's *Principles of Zoology*.) I doubt whether there is another specimen so perfect as this, and I would invite you after the lecture to pass by it and observe it.

The number of joints which allow the animal to move and expand is enormous. One hundred and fifty thousand have been computed in one of them by Dr. Buckland; in others, the number of joints are fewer (Plate XV.), the crown remaining more closed and the rays not dividing so extensively.

These animals which were extremely numerous in former geological ages, agree in the mode of growth of their plates, with the young of that star-fish called *Comatula*, as it has been observed by Thompson. This diagram (Plate I, fig. A.) seems to represent a large animal but it is only highly magnified, the natural size of it being only half an inch long. Nevertheless we distinguish in it the articulated stem with joints. We have the crown above with its solid plates. We have the dividing arm arising from it. We have the surrounding tentacles contributing to seize its prey and bring it to the mouth, and the movable tentacles or suckers along the inner side of the branched rays, which this animal moves as the others use their suckers. In addition to these, there are gradually more tentacles coming out, and the body grows larger, till it is freed from its stem in its perfect condition. The star-fishes which do not rest upon a stem and which do not branch, resemble less those fossils than the types of them in which the rays are more numerous and in which the rays branch (Plate I, fig. B.) But even in common star-fishes in their earliest condition (Plates IV, and X, fig. A.), we have an arrangement of the solid parts which resemble more closely the arrangement of the solid parts of Crinoids (Plate X, fig. B.) than the arrangements of parts in the full grown star-fish (Plate VIII, fig. A.) Compare the solid plate in the young starfish with the solid plates of the fullgrown animal. In the young we have a star in which five large plates seem to alternate with five others, ten of them forming the principle mass of the body.

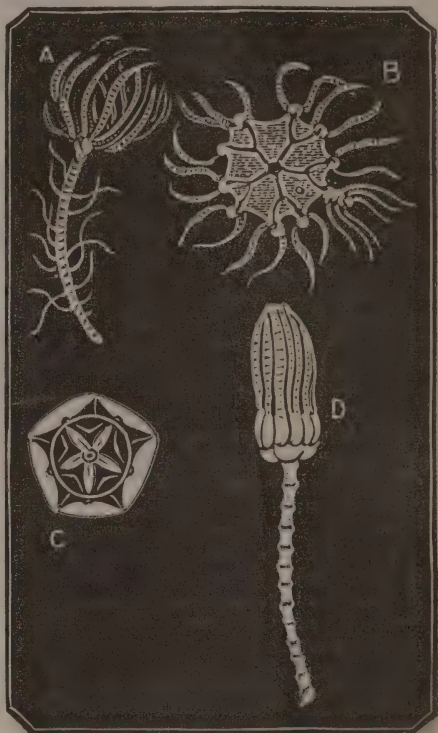
[PLATE X—COMPARISON OF THE CALCAREOUS NET WORKS OF STAR FISHES, WITH THE SOLID PLATES OF CRINOIDS.]



If we take the *Pentacrinus* (Plate XV, fig. A) we observe above the stem a crown, in which five large plates, forming the cup, alternate with five smaller ones. In *Apiocrinus*, the larger plates constitute a hollow cup and above them alternating with them, there are others (Plate XV, fig. B) upon which the branching arms rest. In *Encrinus* crown and arms are not so widely separated and seem to form still an undivided cavity, as in the genera of Plate XVII. (Plate VII, fig. D.) Everywhere the same arrangement exists, so that on a diagram the same drawing would answer for the crinoids and the common star-fishes indiscriminately. Here (Plate X, fig. A) is the central network of the common star-fish, corresponding to the stem of

Pentacrinus, here the five plates which surround the mouth, and those alternating with them, will form the five rays, and so on with successive little plates in all the genera.

[PLATE VII—STAR FISHES—CRINOIDS.]



In Plate X, fig. B, we have the corresponding parts in a diagram of a crinoid, answering precisely in position, number, and mode of growth, the solid frame of the starfishes. In all we find a plan which is uniform, whether we observe such animals in which the young are provided with a stem, or those in which the stem does not appear at all. Even if we go back to the young echini, which seem to differ so much from the starfishes, we have an identical number of primitive suckers, namely, five, (Plate XI, fig. F) which do not give rise to a pentagonal body until the flattened disc assumes a more spherical form (Fig. G). So that there is a most intimate agreement between the different growths of the embryo.

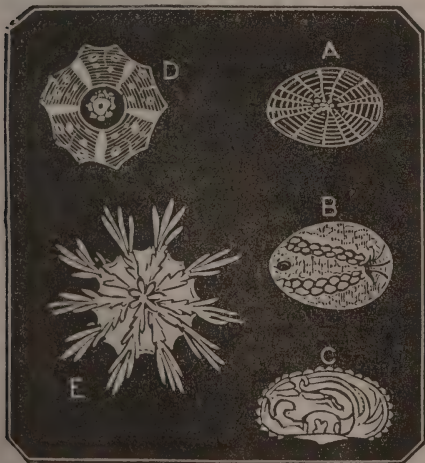
All these data upon the embryonic changes of Echinoderms are very fragmentary, as I have already remarked; nevertheless, with these incomplete series of observations, it can be shown, as I think I have done, that these embryonic forms agree intimately with those which occupy a higher rank in the class, and that they resemble also the form of those which existed in former geological ages.

Would these data afford the means of now in-

producing a natural classification among these animals? is a further question which lays in my plan; as these embryonic investigations were traced from the beginning with reference to the classification of the animal kingdom in relation to the order of all types, when compared with the changes which embryos undergo.

Among Echinoderms the investigation of structure has already settled the classification to this extent, that they have been divided into three families, *Holothurians*, the tubular ones, Plates XIV & V, & V; *Echini*, the spherical ones, Plate XIII; and the *Asterians*, (Plate VIII,) the star-shaped ones: but from this general arrangement there is still a considerable distance to the perfect fixation of the order of succession of genera in all their details. The various arrangements which have been proposed have been influenced by the various states of our knowledge. The improvements in the classification of Echinoderms have been greatly advanced by the knowledge of the Crinoids, which are universally placed in the lowest rank among those animals, from their resemblance to Polyps. When their structure was ascertained, the knowledge thus acquired, did not modify the position which was assigned to them when not yet sufficiently known. The knowledge of the change in the growth of one Crinoid, the *Comatula*, has indeed influenced more the classification than the knowledge of their structure. The free star-fishes are placed next to the *Echini* and above all the *Holothuræ*. Among *Echini* we have some in which the mouth is central and the alimentary canal ends on the margin; and there are others in which the alimentary canal ends on the two extremities of the body, as seen here, (Plate VI fig. B,) thus forming a transition to the worm-like form, they indeed begin to be related to the *Holothuræ* (Plate XIV) and will rank higher.

[PLATE VI—SEA URCHINS.]



Structure and embryonic growth have satisfied us thus far. But why should we not venture to go fur-

ther, and make use of the order of succession of these types, in order to ascertain all their relations? The Crinoids which have been described as fossils, are exceedingly numerous. Here are figured several forms, to which I have not yet alluded. Plate XVII, fig. C, is a genus called *Caryocrinus*. Here is another, which occurs also in old strata, (Fig. B) called *Pentremites*; and here (Fig. D) one which occurs in deposits of the coal period, called *Echinocrinus*.

In Plate XVII, fig. C, we have a spherical body, like an *Echinus*, with a stem as in Crinoids, but the plates are not yet ranged in regular rows (Fig. C), but alternate irregularly; there are not yet rows for the pores distinctly circumscribed, but only at irregular intervals, and few of them. This form, as also the *Sphoronites* are the most primitive Crinoids, and they correspond somewhat in structure to the earliest condition which we observe in *Echini*, and which we observe also in the youngest stage of the star fish.

Here is one (Plate XVII, fig B) in which we have a mere star-fish-like form; the sphere is in its full condition of development; and here we have one which would seem to be a common sea-urchin, (Fig. D.) But on comparing both (Plate XIII, fig. C) they are found widely different. In *Echinus* (Plate XIII, fig. C) there are two rows of perforated and two of imperforated plates, while in *Echinocrinus* (Plate XVII, fig. D) there are four rows of imperforated plates, and the animal is really a crinoid, and not a sea-urchin. This (Fig. D) has a stem: that (Plate XIII, fig. C) has not. The Crinoids are found in ancient geological strata—in the middle geological ages are those of (Plate VII). Free Star-fishes begin later in the geological formations. The *Comatula* or free Crinoids are again later (Plate I, fig. A). The *Echini* appear long after the families of Crinoids and free star-fishes have been introduced upon our globe. We have not yet one of the spherical Echinoderms before the deposition of the red stone or the Marchalkalk of Germany. And those spherical *Echini* or *Cidaris* are the earliest ones, (Plate VI, figs. D and E.) Next we have such as have a central mouth, and in which the alimentary canal ends laterally.

And at a later epoch those which have an elongated body (Plate VI, fig. B.) The first epoch in which elongated *Echini* appear is in the chalk deposit.

When there was not yet one free starfish, there were only Crinoids on earth. And what sort of Crinoids had we? Not such as already resembled common starfishes (Plate VII.), but which resembled the lowest stage of growth of these animals, when they are still without arms (Plate XI, fig. E.) with irregular arrangement of their plates (Plate XVII, fig. C.) Next we have such which assume the shape of the star-fish, (Plate XVII, fig. B.) but are still Crinoids resting on stems with few irregular plates, but in which holes are arranged in a regular star above. And next we have *Echinocrinus*,

(Plate XVII. fig. D.) that is, a crinoidal echinoderm aping the sea-urchins by its spherical form and by the regular arrangement of its plates and by the fact that there are zones of holes, alternating with zones of plates without holes. But that they are not echini is shown by the fact, that they rest on a stem, and that in each row of imperforated plates there are four sets of plates instead of two, as in Echini.

Here crinoids are perfectly developed into the form of higher types, but under the general character of the lowest group of these animals; those forms, however, become more and more individualized in later periods. And here are other Crinoids, (Plate XV & VII) from which free star fishes branch off during the subsequent geological times. But what is most curious, is the fact, that among the Echini, the oldest are the Cidaris (Plate VI, D) spherical bodies somewhat flattened, with large plates, narrow rows of holes, and remarkably large spines in proportion to their proper size, (Plate VII, E) but precisely as we have them in the youngest condition of the true Echinus. (Plate XI, G).—The Cidaris are numerous before any true Echinus occurs. Next, those are developed and become gradually more and more numerous, and they are

soon succeeded by others of a more oblong form and those greatly elongated Echinoderms which we call Holothuriae, occur only in the present period (Plates XIV and V.)

So that by all the facts to which I have briefly alluded, I can come to the conclusion that the class of Echinoderms presents, notwithstanding the imperfect condition of our information upon this point, the most perfect agreement between the various embryonic forms observed and the different permanent forms of the animals of that class in their full grown condition; that these embryonic forms agree also with the different structures of the fossil types through all the geological ages; and that these again in their order of succession, agree with the different appearances of the full grown living animals, or more precisely with their gradation as derived from a knowledge of their internal structure.

These various relations, so complicated, and nevertheless so permanent in every respect, show the same thought throughout the whole—that structure, development and order of succession in time, are regulated by one and the same unique principle.

LECTURE IV.

The result thus far obtained in the lectures which I have delivered, can be expressed as follows: There is a gradation of types in the class of Echinoderms, and indeed in every class of the animal kingdom, which, in its general outlines, can be satisfactorily ascertained by anatomical investigation; but it is possible to arrive at a more precise illustration of this gradation by embryological data. The gradation of structure in the animal kingdom does not only agree with the general outlines of the embryonic changes. The most special comparison of these metamorphoses with full grown animals of the same type, leads to the fullest agreement between both, and hence to the establishment of a more definite progressive series than can be obtained by the investigation of the internal structure. These phases of the individual development are the new foundations upon which I intend to rebuild the system of zoology. These metamorphoses correspond, indeed, in a double sense, to the natural series established in the animal kingdom; first, by the correspondence of the external forms, and secondly, by the successive changes of structure; so that we are

here guided by the double evidence upon which the progress in zoology has, up to this time, generally been based.

Their natural series again correspond with the order of succession of animals in former geological ages; so that it is equally true to say that the oldest animals of any class correspond to their lower types in the present day, as to institute a comparison with the embryonic changes, and to say that the most ancient animals correspond with the earlier stages of growth of the types which live in the present period. In whatever point of view we consider the animal kingdom, we find its natural series agree with each other: its embryonic phases of growth correspond to its order of succession in time; and its structural gradation, both to the embryonic development and the geological succession, corresponds to its structure; and if the investigations had been sufficiently matured upon this point, I might add that all these series agree also in a general way with the geographical distribution of animals upon the surface of our globe; but this is a point upon which I am not yet prepared to give full and satisfactory evidence, and which

indeed does not come within the plan of the present course.

So much for the views referring to embryology in its bearing upon zoological classification.

There is, however, another field in which the animal kingdom has been represented as developed according to the gradation of its structure: I mean the order of succession of extinct species in geological times. It has been long and generally asserted, especially by the physio-philosophers, that the lower animals were first introduced upon our globe, and formed alone the population of the earliest periods in past time; that Polypteri existed before Mollusks; these before Articulata, and that Vertebrata were the last to make their appearance. But the discoveries in fossil Ichthyology, which it has been my good fortune to describe in my researches upon fossil fishes, have shown that vertebrated animals, fishes, have existed in the oldest epochs, and that such an order of succession, as mentioned before, did not agree with the plan of creation. Indeed, that representatives of all the four great divisions of the animal kingdom, Articulata, Mollusca and Radiata, occur simultaneously with fishes, in all the lowest geological formations, was soon ascertained by the investigations of paleontologists, and the fact of any regular succession was afterwards altogether denied. However, the simultaneous occurrence of the four great types does not yet indicate the want of regularity in the development of the various classes of the animal kingdom, taken isolately. Several eminent paleontologists, Leopold Von Buch, Count Von Murster, Sir R. Murchison, d'Orbigny, Prof. James Hall, and many others, have shown that the types of different classes which characterize the different geological ages, follow each other in an order which agrees with their zoological gradation as ascertained by structural evidence. The great difference between this fact and the views entertained before, consists in the knowledge of the independent gradation of the different classes, which in the lower types arise all simultaneously, to undergo their metamorphoses simultaneously, through all geological periods, whilst among Vertebrates, the Fishes were found to occur earlier than Reptiles, and these earlier than Birds and Mammalia, which made their appearance last. It was in that way shown that there is a progressive succession of classes among Vertebrata, ending with the creation of Man; whilst Polypteri and Echinoderms among Radiata; Acephala, Gasteropoda and Cephalopoda among Mollusks; Worms, Insects and Crustacea among Articulata, existed simultaneously during all great periods, and presented each a development of its own.

However, another step had to be made to show a real agreement between the earlier types of animals and the gradual development of the animal kingdom, which has been the last progress in our science of fossils: namely, to show that these earlier types are embryonic in their character—that is to say, that they are not only lower in their structure when compared with the animals now

living upon the surface of our globe, but that they actually correspond to the changes which embryos of the same classes undergo during their growth. This was first discovered among fishes, which I have shown to present, in their earlier types, characters which agree in many respects with the changes which young fishes undergo within the egg. Without entering into all the details of these researches, I will conclude by saying, it can now be generally maintained that earlier animals correspond not only to lower types of their respective classes, but that their chief peculiarities have reference to the modifications which are successively introduced during the embryonic life of their corresponding representatives in the present creation. To carry out these results in detail must now be, for years to come, the task of paleontological investigations.

But the other connections mentioned above, I consider as established, and I claim these views as the results of my own investigation, though much has already been said upon the natural and successive development of the animal kingdom, and upon the propriety of introducing a classification based upon embryology. The views to which I allude are indeed not the same as those which I advocate; and in order to avoid mistakes in this respect, I will now dwell for a moment upon this point, with the hope, perhaps, to show that these views are incorrect, and must be given up, though they pretend to lead to a natural arrangement of the animal kingdom. The first notion of progressive development of the animal kingdom, of an agreement between the order of succession of types and their structural gradation, has been brought forward by that school of philosophers who in Germany take the name of nature-philosophers, (physio-philosophers.) But with them the idea of a gradual development of the animal kingdom, was by no means the result of investigations—was not the expression of facts, but was an *a priori* conception, in which they made their view of the animal kingdom the foundation for a particular classification, seeming also to agree with the little that was known of geological succession of types.

Dr. Martin Barry, a distinguished physiologist in London, has however proposed principles for classification, of the animal kingdom, which deserve more particular notice, as he presents them as the results of his extensive investigations in embryology, and he has put his view upon the subject in the following words. Dr. Barry is one of the ablest investigators in this department, one of those who have most extensively studied the egg and its developments in the mammalia. To him and to Dr. Bischoff we are indebted for the most elaborate investigations upon this subject; but I am not aware that Dr. Barry has traced the metamorphoses of animals in other classes. His views are substantially expressed in the following statements: "There is no appreciable difference in the germs of all animals. There is a fundamen-

tal unity in all of them." This is a result which is beyond all doubt, which is beyond all controversy. The eggs in the whole animal kingdom are identical in structure. However, this fundamental unity must be restricted in one sense.—They are identical in structure for our senses, but we cannot consider them as identical in a higher point of view, as from each kind of egg there will never arise but one kind of animal; there is an essential, though not a material difference in the egg from the beginning; but in their material structure the eggs of all animals are identical.—The first position must therefore be granted; but with the restriction upon which I insist, that though identical in structure, there is something which presides over the individual growth, from the beginning even of the formation of the egg, and makes each one give rise only to one sort of animals. It could, then, just as well be said, that the eggs, though apparently uniform, are essentially different in different species. But Dr. Barry states that the class, or the characters of the class, become manifest in the egg in the germ, before the order can be distinguished. That is to say, that the first change which takes place in the embryo, is to bring forth in the new animal what characterises it as belonging to one particular class.—For instance, that a young rabbit would first assume the peculiarities by which it is referred to the class of Mammalia. Next, the order becomes manifest; but the family is not yet shown. The young rabbit would be distinguished as belonging to the gnawing animals. Next the family (here the family of Hares) becomes manifest; but the genus not yet known. Next the genus (*Lepus*) obvious; but not the species. Next the species (Rabbit) distinct; but the variety unpronounced.—Next the variety (white, grey, black rabbit) obvious; but the sexual differences scarcely apparent. Next the sexual character obvious; but the individual character not noticed. Next the individual character developed in its most special form. This is very logical, but not in accordance with nature; we may frame such a system in our closets, but it does not answer our observations.

Let us remember what we saw in the egg, with which I began illustrating the growth of frogs.—Was it the character by which the frog is found to belong to the class of reptiles, which was first apparent? By no means. It appeared first, under the form and with the structure of a fish, and not under the form and with the characters of a reptile. The lowest form of vertebrated animals was first developed in the earlier changes of the egg, before the class to which that animal belonged could be recognized. Not only would the first form under which the young Batrachian appears, exclude the class to which it will belong afterwards, but even the internal structure of the tadpole differs from that of the reptiles. They have no lungs, no internal aërial respiratory organ, nor even a rudiment of it, and also no nostrils communicating from

outside with this inner hollow sac. What did we find among the starfishes? among the echini?—Did we recognize there the hard plates or the rows of regular plates which mark that class, or the rows of suckers? By no means. Forms which would lead us to mistake them for Polypteri or Medusæ were first noticed, and not the indications of their class; thus showing that there is no such thing as an earlier development of those characters which indicate the respective class of the animals under observation in the progress of embryonic growth.

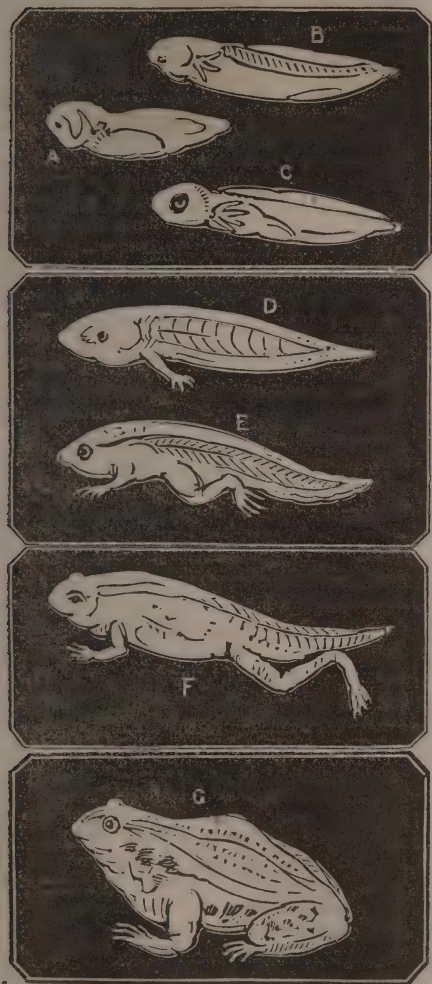
Next, it is said that the orders are manifest, but not the genus. But let us take as a test the embryo of a very well known animal among mammalia. To what order does the cat belong? To the Carnivora and to the family of Digitigrades.—What are now the characters of carnivora? Sharp-pointed, canine teeth, with chisel-like incisors and various molars, the principal one of which is a sharp-cutting tooth. The claws again, are strong, curved nails, adapted for their peculiar mode of seizing their prey. Now, the young cat is already far advanced in its development before it has any teeth at all, and its paw is a real fin, with undivided fingers, and without nails in the earlier stage of growth. We have at first, therefore, not one of those characters which distinguish the order of Carnivora and the family of Digitigrades; and nevertheless such an imaginary order of succession in the development of parts is made the fundamental principle of a system which is given as natural, though the whole is merely a logical partition of principles.

The genus next should be shown. What are the characteristics of the genus, cats? To have four molars in the upper jaw, and three in the lower. But before the cat has all its teeth, the genus can be recognized, by its protractile and retractile claws. The species indeed, is ascertained, is well characterized, by its peculiar form, before we can refer it to the genus, according to its zoological characteristic. But it is said that the variety becomes next obvious. The cat, however, may have already assumed a peculiar variety of color; it may be a grey or a white, it may be of any color before the teeth, the characteristic of the genus, are fully developed. And as for its individual character, the young kitten is playful, and shows its character long before its peculiar genus is marked out; and in short, every thing takes place in the reverse order from what it is supposed in this system. Nevertheless, such views are considered as suited to express the real gradation in the animal kingdom, from the simple reason that the whole statement seems natural and logical.

A renewed examination of the metamorphoses of the frog will lead to the same conclusions. At first we do not observe changes indicating the class to which that animal belongs, but such characters as would rather indicate the class of fishes; nor are the characters of the order of batrachians

developed before the young animal assumes forms related to genera to which it can never be referred. Indeed, the tadpole has all the peculiar appearances of batrachians with permanent gills, before a frog can be recognized; it resembles successively *Menobranchus*, *Triton*, and *Menopoma*, before it loses its tail; and as for toads, they have webbed feet, that is to say, they resemble another genus, the frogs, before their fingers are entirely separated, though the species can be recognized in the distribution of colors long before.

(PLATE III—FROGS)



Professor Milne-Edwards, of the Jardin des Plantes, has proposed similar views, and indeed expressed in nearly the same words, his conviction about the gradation of the animal kingdom; but not with reference to the development of zoological characters, but with reference to the changes which the animals undergo in their structure. He

has referred his views more particularly to the structure and the development of the functions of animal life; and from this circumstance his views agree better to nature, when he says that those organs are first developed which are more important to life. However, strictly speaking, it is not absolutely true. It is the nervous system which we may consider as the organ most important to life; and it is not the nervous system which becomes first apparent in the embryonic changes. The systems by which the body grows are developed before those by which it lives a higher life come into play; so that, though in a general way, the organs most important to existence are really developed first, it cannot strictly be said that they are the higher organs which are developed first; and that the special differences which characterise families and genera should be engrafted as it were upon a fundamental plan.

My aim is an entirely different one, as you may have perceived from my first lecture. It is to show that in the real changes which animals undergo during their embryonic growth, in those external transformations as well as in those structural modifications within the body, we have a natural scale to measure the degree or the gradation of those full grown animals which correspond in their external form and in their structure, to those various degrees in the metamorphoses, and therefore to make the metamorphoses of animals, as illustrated by embryonic changes, a real foundation for zoological classification.

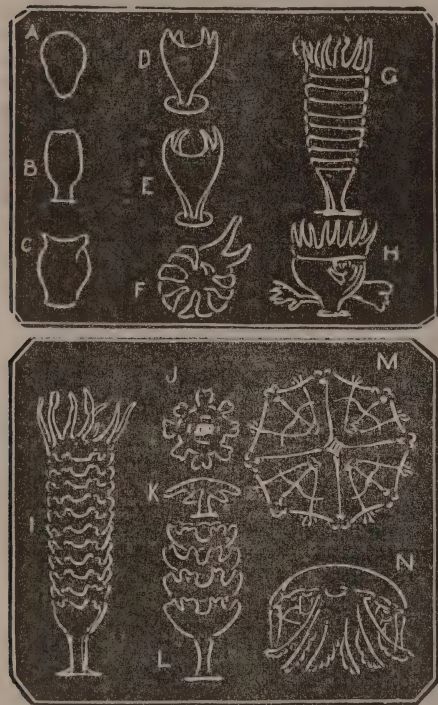
Let me only mention that on the whole, the higher families of the various classes of the animal kingdom are distributed over the warmer parts of the present surface of our globe, and that the lower families are rather numerous in the milder and colder regions. Thus among mammalia, the Monkeys are strictly circumscribed within the limits of the growth of Palm trees; the large carnivorous beasts prevail in the tropical regions; whilst the sheep, goats, and oxen are natives of the temperate zone; among reptiles, the crocodiles occur only in the warmest countries; whilst the lower Batrachians, those with external gills or permanent tail, extend even far north. There are, nevertheless, inferior families which are also strictly tropical; such for instance as the *Pachyderms*, and to some extent, the *Edentata*; but this fact has doubtless reference to the early introduction of these families in the plan of the creation, during a period when the surface of our globe was warmer than it is in our days; so that the location of their modern representatives in the torrid zone, can be considered as merely determined by the peculiar adaptation of their general plan of structure for warmer climates, rather than related to the gradation of the types, according to the present condition of the distribution of heat upon our globe. The inducement for their present location is not their higher structure, but their relation to earlier types.

But now, I proceed to illustrate the history of

another class, that of Medusæ; the next among radiata, whose embryology we have to investigate. But it is out of the question to understand the changes which Medusæ undergo, without knowing their structure, and this structure is not only very complicated, but it has been little studied and is still obscure. I stand, therefore, with a very difficult task before me, and I ask your indulgence upon this point.

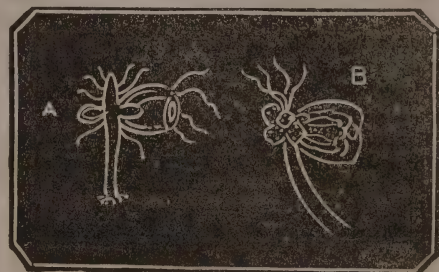
Let me begin by pointing out a few diagrams, and saying a few words upon the figures before you.

(PLATE XIX.—YOUNG MEDUSÆ.)



Here (Plate XIX, fig's A B G) are outlines of a family which has been described by Sars, the distinguished Norwegian naturalist, as a peculiar polypus, under the name of Scyphistoma. Here (Fig. I) are other figures, which have been also described by Sars as polypes, under the name of Strobila. Here (Fig. J) is another free animal, described under the name of Ephyra. And here (Fig. M) is another, found on the shores of the Atlantic, both in Europe and in the United States, in the temperate zone, which belongs to the genus medusæ. As to the class to which these various animals belong, I may mention that the two genera, Strobila and Scyphistoma, were referred to polypi, and the other two (Fig. J M) to jelly-fishes, or Medusæ. Now, gentlemen, it has been ascertained within a few years, both by Sars and Von Siebold, that all these figures are the various

stages of growth of one and the same animal.—We have here (Plate XIX) the metamorphoses of one and the same animal—changes which take place in the growth of an egg. This (A) is an egg, as it is laid by a Medusæ. Here (Plate XX, A) (PLATE XX.—POLYPI—CORYNÆ, SYNCORYNÆ, PODOCORYNÆ)



we have a still more extraordinary structure (syncoryna). You see these stems terminated by a rosy colored head, from which tentacles, half a dozen or more, arise, and out of these various bodies, a little tubercle here, a more prominent one there, and another bell-shaped here, with tentacles around its opening. Here is another form (Fig. B) called Podocoryna, by Sars, from which various kinds of buds arise, which do not resemble the primitive stem; also much larger buds, which differ still more, and which are at a certain time freed and grow into other animals. Indeed, stems of polypi, from which arise buds of medusæ or jelly-fishes, budding from polypi-like stems, becoming free and growing into a regular, simple, isolated jelly-fish, like this (Plate XIX, N); this is the case here, (Plate XX) a bud which grows into a jelly-fish. It is, however, out of the question, that in its different stages of growth, an animal could belong to various classes, or that an animal of one class could give rise by budding to animals of another class. Therefore, it is perfectly obvious, from the nature of these well authenticated facts, that there has been a want of understanding of these phenomena when they were first described; and it was not until a few years ago, when Steerstrupp found out the key to this astonishing complication, by ascertaining that there is an alternation in the mode of reproduction of many animals, which takes place in different ways in the animal kingdom. In some, there are eggs laid, which eggs give rise to animals different from their parents, and these in their turn give rise to eggs, from which arise animals similar to their grandparents and different from their parents.—In other cases, animals lay eggs which go to form individuals different from themselves, and these individuals, by budding, or transverse division, produce forms which are freed, grow, and then resemble the parent, by a complicated process of metamorphoses.

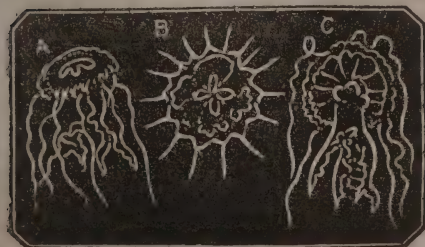
However, though Steerstrupp, for the first time, brought out these conclusions distinctly, he was

somewhat anticipated by Sars, by Sir John Dalyell, and by a French naturalist, Du Jardin; though they did not carry out their investigations to the same purpose, yet they led the way in the same track. How these changes take place, will be I suppose better understood, if I begin by giving an outline of the structure of these animals, which it has been possible for me to examine more completely than it had been done before; availing myself of several small species which live in Boston harbor. The large animals are not those which are best suited to such investigations; when large their bulk prevents their being examined under the microscope. But let the animal be small enough to be placed entire under the microscope and you get a general view of the structure; and by applying a higher power to the various parts, you can trace the details in such a way as to ascertain most completely their organization. Such was the process by which I was enabled to discover in these minute medusæ, even the nervous system, which had been only suspected, but not traced in its distribution. And let me add, that beside their physiological interest, these animals are wonderful in their aspect, and present the most attractive sight which can be witnessed. Their transparent, delicate bodies swimming freely in the water and moving regularly by the contraction of their whole mass—the elegance of their outline and the diversity of the appendages which hang down from their globular body—or the suckers which rise from the centre, and constitute other appendages from the middle of the sphere—all these contribute to make these animals wonderfully beautiful. An increased interest is felt when seeing at first scarcely an outline, so transparent are they, and discovering afterwards by the simplest process of examination, consisting in modifying the light which passes from the mirror of the microscope through their body, all the differences of structure so easily overlooked at first sight.

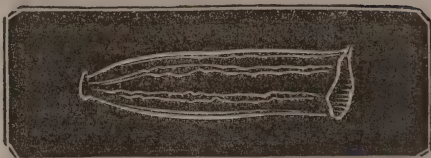
And again, they belong to a class of which so many are transparent, or phosphorescent, that there are endless inducements to investigate these animals. Here are various figures (Plates XXI, 'II, 'III, 'IV, 'V, 'VI, 'VII); all representing Medusæ.

Many of these figures are of a hemispherical form, as plate XXI; and this form (Plate XXVII, fig. B). In the margin of this form (Plate XXI, fig. A) you see we have two kinds of appen-

[PLATE XXI—MEDUSÆ.]



[PLATE XXII—MEDUSA.]



[PLATE XXIII—MEDUSA.]



dages, and you see (fig. B) that there is a central cavity, and that there are four bunches of a peculiar character here, the ovaries, (fig. C), and that the lower surface presents various rays diverging towards the edge. In another form, Beroë, (Plate XXII) we have a tubular body with vertical rows of vibrating cilia, and a wide opening below the internal cavity, which is more complicated than that of the other types. Here is (Plate XXVI) another, Agalmopsis, which is still more complicated, from the diversity of all the appendages which hang from the main stock; and here is another, which is, if possible, still more complicated, and has a very large vesicle above and numerous tentacles hanging below. This animal (Plate XXII) is known to the sailors by the name of Portuguese Man-of-war. Naturalists call it Physalia. Others are flat, circular, or oval, with several rows of simple appendages, as Velella, plate XXIV, and Porpita, plate XXV.

[PLATE XXIV—MEDUSA.]



Professor Eschscholtz, who has studied these animals more extensively than any one else, has divided them into three groups—Ctenophora, Discophora, and Physophora. Those which have these vesicles, by which they are suspended in the water, are called Physophora. They are all considered as simple animals, though their form is extremely complicated. Here is an enlarged fig.

[PLATE XXV—MEDUSA.]



are (Plate XXVI) of one of these animals, with all various appendages—tentacles, suckers, groups of eggs, and all sorts of vesicles—forming one elongated body, with fringes. It is the *Agalmopsis* of Sars. Let us now see what is the structure of these animals. The internal cavity communicates with the exterior by a broad open mouth, as you see in this sketch, or by bunches of tentacles which terminate in little suckers, as you observe in this figure (Plate XXVII, fig. B)—numerous suckers hanging down from the central appendages and forming as many mouths, as many openings communicating with the central cavity, as there are such appendages. In another case (Plate XXVII fig. A) we have simple little openings, or pores, upon the surface of the larger appendages, all directed inwards, uniting and combining to form larger stems—finally combining into fewer tubes and emptying into a main cavity, and from that main cavity branching off again into numerous tubes, and dividing over the margin of the disc. Those ramifications from the central cavity towards the surface can be easily seen by holding the light in a certain angle before these animals in their living condition. And by injecting colored water, you may fill them in all directions, and see that there is, as in plate XXVII, fig. A, a net work of vessels ramified around the animal.

There are others, [Plate XIX., fig M.] in which there are main stems, which divide into some few more towards the margin, or unite again into a circular canal all around the edge.

There are even some in which the central cavity [Plate XXVIII.] is very small, having only a little sack at the summit of a long proboscis, which is the

mouth; the little sack next divides into four tubes, which then extend towards the edge, where they unite again to form a circular tube. Liquids are constantly circulated in these cavities. The food is digested within that cavity and then circulated through the tubes, and in those which have only minute pores as oral apertures, the food can consist only of microscopic animals, or of decomposed organic matters—in others which have a larger mouth, larger animals are introduced. In the small species of Boston harbor, [Plate XXVII, fig. C.] which was first described by Dr. Gould in his Report upon Invertebrate Animals of Massachusetts, and which will be exceedingly common in a few weeks, I have seen this proboscis hanging down and stretched three times the length which you see here; and after it had swallowed something, and the food had been digested, the globules arising from the digestion would be circulated through the tubes and would be seen under the microscope most plainly, diverging towards the margin of the sphere, there moving into the circular tubes, or perhaps even moving down into the appendages—those hanging arms which are hollow—and again trace back their course into the circular tubes; some of the globules would disappear when absorbed by the surface, but the remainder is circulated forwards and backwards—to and fro—in those tubes before disappearing entirely.

Such a structure can be considered the lowest condition of a system of circulation, which is at the same time a modification of the alimentary tube, where the stomach divides, and where the divided stomach again unites into vessels—into common vessels, which branch in their turn. Here we have the tubes uniting and then branching off again, [Plate XXVII, fig. A.] but in Fig. C there is a distinct mouth and proboscis.

The mass which forms the body in medusa is transparent and cellular. And then there are distinct muscular fibres of two kinds, circular ones around the whole disc, and radiating ones, which form distinct bundles diverging from the centre towards the periphery; in those medusa which have four diverging alimentary tubes the main radiating muscular bundles alternate with the tubes (Plate XXVII, fig. C.) All these muscular bundles and the circular fibres contract alternately, so that the body can be shortened or flattened in various ways, and thus, through the agency of these muscles, the animal moves in all directions, upwards, sideways and downwards, at will. That these animals moved by contraction, had long been observed; but the existence of regularly arranged muscular fibres in the class of medusæ, was still doubtful. When Ehrenberg published his investigations upon the structure of the medusæ of the Northern Seas, though he concluded that there must be muscular fibres, he could not discover a regular, complete, muscular system. However, in these small medusæ, the muscular fibres are large

[PLATE XXVII—MEDUSÆ.]



enough to be seen in the living animal, under a power of a few hundred diameters.

Beside this, there is around the upper part of the alimentary tube, a linear circle of another substance, from which radiate four threads, following the direction of the alimentary tubes, and extending towards the periphery, which reach there the spherical, colored bodies, now generally considered as eye specks, and uniting with each other, form a circular thread all around the margin of the disc. This apparatus I consider to be the nervous system. Its position is the same as in the other radiated animals, a circle around the alimentary tube, with diverging rays, ending in the small colored organs which since discovery (Plate XIX, fig. M) have been considered as Ehrenberg's eye specks, similar to those which I have already noticed, at the end of the rays of star-fishes, and upon the plates of Echinoderms. The fact of these threads going to those spots (Plate XXVII, fig. C), leaves no doubt, in my mind, that it is a complete radiating, nervous system, similar to that of star-fishes. So that the structure of medusæ, though peculiar in itself, by the remarkable mode of distribution of its inner cavity, which does not constitute an alimentary canal proper, resembles almost entirely the structure of Echinoderms, and constitutes one of the main classes among Radiata as Echinoderms do. The position of these animals was mentioned. They swim free, the mouth downwards, the sphere upwards; and this is all

ways the position which the Echinoderms assume. The Echini, Sea Urchins, walk about, the mouth downwards. Star-fishes walk about, the mouth downwards. The Crinoids, however, stand upright, the mouth upwards, and this is the position which the animals of the lowest class assume.

In all Polypi, the main body stands upon a stem, the mouth upwards; and we have also among Medusæ [Plate XIX, figs. G & I] a similar condition under one period of growth.

When the young animals are fixed by the lower portion of their body, the tentacles, or appendages, which every where hang downwards, stand here upwards; so that you see how remarkably the lower types among Echinoderms resemble in this respect the Polypi in their constant position, and how in youth, Medusæ, in that respect also agree with Polypi. There is a constant recurrence of characters from one of these classes to another. They are interwoven in a most remarkable manner.

All Jelly-fishes are generally considered as simple animals; but I am satisfied that there are, on the contrary, highly complicated ones among them. The Physophora differ indeed widely from the other Medusa, by their diversified appendages, as is shown by the structures figured on this diagram. [Plates XXIII and XXVI] I am prepared to show that these are compound animals, composed of groups of individuals of different kinds; indeed, compound animals as we find them among Polypi.

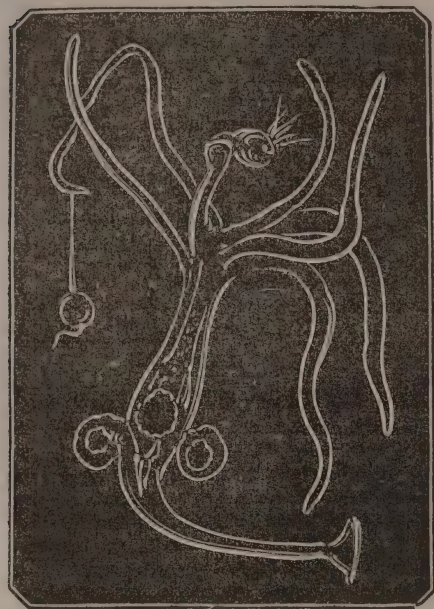
[PLATE XXVIII—HYDRA—CAMPANULARIA.]



In order to show that this is the case, let me illustrate in detail the metamorphoses of Medusæ. Let me also refer you to some Polypi, [Plate XXVIII] in which you see how individuals are combined together, forming a compound stick. Though all these individuals are of different ages and have been found successively, they form living colonies, as it were, of successive generations, united by material connections, which remain for life—the new individuals not separating during life. In others, the successive buds may be more or less different, and nevertheless remain united in one common colony, or as it were form a community of individuals closely united, though differing in age, size, form, and even in sexes. Such is the case at least in the Campanularia, figured Plate XXVIII. But there are also among Polypi simple ones, like this little Hydra, [Plate XXIX].

When alive the Medusa lays eggs, and the embryos are hatched, these germs swim freely, and then become attached. And the point by which they become attached grows longer [Pl. XIX, B], in proportion as the mass above grows larger. The

[PLATE XXIX—A FRESH WATER POLYPUS, WITH A SIMPLE CAVITY AND A MOVEABLE STEM.]



vibratory cilia, by which they first moved, are finally cast. There is a depression forming upon the summits, and then two little horn-like appendages grow out. [Fig. C.] They grow larger. [Fig. D.] The tentacles grow longer, the depressions still deeper, and then there is finally a central cavity with four distinct tentacles. [Fig. E.] Then there will be a little Hydra like animal, with eight tentacles, a central cavity, and a peduncle by which it is attached. [Fig. F]

This is the first development of the germ of the common medusæ, the jelly fishes of this shore, which are known in Boston harbor under the name of sun-fishes. When it is grown somewhat larger, a contraction takes place under the rows of those tentacles, which have become more numerous. In this stage of growth buds may also be found. (Fig. H) New individuals may thus arise from buds on the sides of this simple stem, and these new individuals may grow to a considerable size with the parent stalk before they separate. But at last they will separate, and grow by themselves and form new sticks. So that we have here two modes of reproduction among medusæ; in the first place, from eggs, which grow into polyp-like animals, (Plate XIX. fig. A—F) and secondly, by buds which will produce new individuals, (fig. H.) The bud being separated from the main body, will even form new colonies, and so on. (Fig. H.) At first these buds differ somewhat from the parent stock, but soon assume the same character, differing slightly when they are finally freed.

There are animals in which the successive buds differ much more. There are in this (Plate XXVIII) *Campanularia*, as it is called, buds which give rise to animals with large tentacles, and there are others with shorter tentacles, and there are even others of a different type; so that the various buds which grow from one stock may differ widely and yet be buds of one and the same stock.—Here, in the young Medusæ (Plate XIX) we see that only one kind of buds arise—but there has been still another mode of reproduction and multiplication observed in the same animal (Plate XIX, fig. I.) The stem, on growing longer and higher, (Fig. G) will begin to divide by transverse contractions into articulations. There are at first, simple folds noticed in the skin, scarcely deepened to any extent, but gradually growing deeper and deeper, so that at last it seems as if a pile of discs were heaped upon each other, (Plate XIX, fig. I.) the lower part of which is a simple stem, as in Fig. G, and the upper part, still consisting of a row of appendages as they have grown upon the summit of this little Polyp and Serrate (Figs H and G). Next, the edges of the discs begin to be fringed, (Fig. I.) the cut growing deeper and deeper, these serratures assume a regular form, and the contraction growing successively deeper and deeper, those serrated discs, almost separated from each other, form a pile of loose discs simply connected by a central axis. And as soon as the Polyp has divided into this series of discs, the upper tentacles, that is to say, the tentacles of the primitive Polyp, with the upper disc, die away. What formed first the principal part of the growing animal, dies away, except the basal attachment, which remains; and next, in the remaining pile, the uppermost disc frees itself from the pile and begins to swim. But the moment it is free it assumes an inverted position, (Fig. K); those fringes which were upwards, now are turned downwards. The inner surface, which was first upward, is now downward also. In this way, a series of these serrated discs (Fig. L) are successively freed from a primitively undivided stem, by gradual transverse articulations, to form as many independent individuals (Fig. T), which after all can be traced to one single egg.

There are finally quite a number of individuals formed, which have arisen simply by transverse division, and by the successive modifications which each of these discs has undergone. And, after freeing themselves, the Ephyrae, as they are called, (Fig. J M) will undergo such changes as to assume those structural peculiarities which characterise the perfect Medusæ. The tube will become hollow. The cavity will enlarge, and that will have its tubes, branching into the disc by various canals, (Fig. M) Those canals will circulate fluid around the disc, and finally the complicated structure of Medusæ (Plate XIX. Fig. M.) is produced by the addition of fringes on the edge; and the growth of processes on the side of the stomach which give rise to the egg, the eggs always hang-

ing from the sides of the stomach, being, indeed, simple pouches from the stomach. I ought to have mentioned before, that the eggs in *Medusæ* are universally formed in connection with the alimentary tube, and that in some of them, as the small species of Boston harbor above described, they are simply diverticula of the digestive cavity, formed in coecal appendages of the same, to become free, independent eggs afterwards. Their position varies even most remarkably along the alimentary tubes, in some, that before mentioned, being developed along the central proboscis; in others, the *Stomobranchium*, being formed in four bunches along the four tubes diverging from the central cavity. Their mode of formation in such positions has nothing more to astonish us, since we know, from the investigations of Sars, that there are *Medusæ*, the *Cythers*, in which new individuals are developed from buds arising from the stomach. At a certain epoch the whole generation produced, arises by transverse division of the stem derived from the eggs of the *Medusæ*, producing a number of connected individuals, from the sides of the primitive stem (Plate XIX. Fig. H); there are also often found buds growing upon the lower portion, but invariably, at some period, the perfect *Medusæ* will produce eggs.

In some *Polypi* we have also eggs arising from the sides, like buds as in *Hydra*. [Pl. XXIX.] We have here, [Plate XX] from *Polyp*, *Syncoryna* and *Podocoryna* buds arising which differ entirely from the main stock, but which are successively freed from it, and which give rise to animals which are metamorphosed into real *Medusæ*. Instead of being considered as *Polypi*, those beings should no longer be considered as perfect animals—should no longer be arranged in our systems by themselves, any more than *Ephyra*, the larva of *Medusæ* [Plate XIX fig. J.]; any more than *Strobila* [Fig. L.] or *Scyphistoma* [Fig. E.]. They are only to be considered as the stages of growth of *Medusæ*; in some of which the regular *Polyp* divides into many buds, forming as many *Medusæ* [Plate XX fig. B.], or in others, of which simple *Polypi* give also rise by budding to regular *Medusæ*, there being simultaneously other modifications of the processes of budding introduced, by which the animal is finally brought to its higher metamorphosis, [Fig. A.]; the budding being [Plate XX fig. B.] the step by which the higher metamorphosis is introduced. The free individuals, which differ so much from the parent stock, being finally cast off.

In *Medusæ* proper the budding does not introduce the higher metamorphosis; this taking place only in the individuals formed by transverse division.

Now, let us for a moment compare such a being as *Agalmopsis* (Plate XXVI) with the dividing stock of *Strobila* (Plate XIX, fig. I). We see at once that their position is inverted. Here (Plate XXVI) the fringes hang downwards, but here (Plate XIX, fig. I) they are upright. To institute

a close comparison, we must therefore consider them in the same position, and the resemblance will be striking, especially towards the narrow end. But when we know that in *Polypi* buds of various aspects can arise from one stem, and remain connected with the cavity of the main stem, as it is here shown in *Campanularia* (Plate XXVIII)—the connecting axis being the main body with a continuous cavity which extends into the branches—we have no reason to wonder at a similar growth in animals like *Strobila* (Plate XIX, figs. G and H) where there is also a similar connection between the bud and the main cavity of the body.

And now in *Agalmopsis* (Plate XXVI) instead of considering those various appendages as organs of a simple animal, let us for a moment inquire if we could not consider them as buds of various kinds remaining around one stock, and forming a community of heterogeneous individuals, living a common life, in the same manner as in *polypi*, where we have observed individuals, though somewhat heterogeneous, living also a common life. And if this comparison can be carried out, we have established that *Agalmopsis* must be considered as a community of distinct individuals.

Now, what are, in the first place, those largest bottle-shaped appendages? They are considered as suckers. But they are suckers which pump food, which digest it in each of these bottles.—There is a cavity in which the food is digested; and the result of this digestion is circulated through the main tube. It is a condition identical with the condition of the *polypi*, in which a new bud arises to remain connected with the main body, to have, however, a cavity of its own in which to digest food, and then circulate it with the main mass. Here (Plate XXVI) is another kind of suckers, but performing the same function. They are similar individuals in a lower degree of growth.

At first these bottle-shaped open suckers are small, simple appendages from the main tube, which grow larger and finally assume a more individualist life, so that we would have eating individuals upon a common stem, which provide the whole community with food. They are the mouths, the eating individuals—other appendages which seize upon the prey and which bring it to the suckers, may be considered as compound stems. Of these apparatuses here is one highly magnified: you have first, the bottle-shaped apparatus with their various modifications. Here we have the netting organs, which are, when highly magnified, also bottle-shaped, and from which threads hang down. They are another kind of individuals, suspended by their peduncles and from which fringes hang down—but not simple individuals. They are individuals which bud in their turn, so as to form groups of individuals—groups of catching individuals.

Then there are other buds, which remain hollow cavities, and are considered as vesicles to suspend the animals. It is the swimming apparatus of the

body; but this form resembles so much that of the suckers, that they must be considered simply as a modification of them.

And if the suckers are buds, these must be closed buds. Then there are still other buds, which remain closed, and which gradually swell and sink. They do not assume so much individuality as to open outside, and to perform other functions. Admitting simply the fluid within, and pushing it out again into the common cavity.

Such buds are imperfectly developed individuals, performing the function of respiration.

They are individuals to breathe, as there are individuals to seize the prey; as there are individuals to digest, living upon one common stock. There are other individuals which bud also, and they are ovaries. Here, Fig. XXVI, apparently an organ, but nevertheless, arising like the other buds—reproductive individuals, and of these there are even two kinds—such as assume the form of bunches of grapes, and others which assume the form of those small *Medusæ* here, (of Plate XX. Fig. B) and which occur, especially in the lower portion of the animal—swim away freely, and reproduce free individuals.

Now if it was not for these cases—such buds which may reproduce the whole colony—such a conclusion as I am about to present would seem untrue. But, when there are some among these various buds which actually present the structure of *medusæ*, we must conclude that the so-called

Physophoridae are compound animals, in which the various functions of the body of *medusæ* are distributed to different individuals in a most diversified manner, they being, however, not organs of one animal, but of a community of individuals, each performing special functions; the whole exemplifying what a well regulated Society should be.

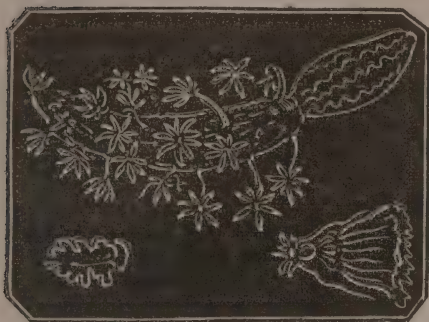
There is the most remarkable resemblance between the mode of association of individuals in the compound animals which throw out buds, connected with the primitive stock, and the plants which produce successively buds of different kinds. Indeed the branching of trees from buds compares in all its features with the budding of compound animals, and the similarity is closer in proportion as there are more buds of different kinds produced, which through life are confined to particular purposes; for instance, plants which produce similar buds, growing into branches, identical with the main stalk, will compare with the simpler forms of compound animals, in which all the buds produce individuals similar to the primitive stem. Plants, on the contrary, which produce at various periods leafy buds, and flowering buds, in which the male and female flowers may even be separated, will compare more closely with compound animals, consisting of heterogeneous buds which remain generally united for life, and from which only from time to time eggs, or peculiar buds, are detached, like seeds, to produce new individuals and new communities.

LECTURE V.

After illustrating the structure and embryonic development of the Jelly-fishes, I did not draw any conclusion in my last lecture as to the natural classification of these animals; because I wanted first to examine more closely the class of *Polypi*, in order to trace, if possible, defined limits between these two classes. Indeed, there is great difficulty in ascertaining the proper limits of the class of *Polypi* as a natural division of the animal kingdom, owing to their low position in the series. Their structure is so simple, that they are apparently related to all the lower types of other divisions. And indeed we find that animals of very different types have been referred to the class of *Polypi*. There have been articulated animals brought in connec-

tion with them. There have been *Mollusca* referred to that group. And even at the present moment, after anatomical investigations have thrown so much light upon this subject, I incline to admit that the class of *Polypi*, as it is now circumscribed, is by no means a natural one; and intend this evening to show that entire groups, considered by all naturalists at the present moment as *Polypi*, will have to be removed from that class, and that other types, which are referred to other classes, will have to be combined with this class.—It will be perhaps best to begin this illustration by pointing out the various forms which are thus combined at the present moment as one class, under the name of *Polypi*.

[PLATE XXXIV—VERETILLUM.]



We have here diagrams (one of which, Veretillum, is given in Plate XXXIV) of the principal groups of this class; and indeed there is scarcely one family of Polyeps of which these diagrams do not represent some species. The Corals are among those which have from the beginning been considered as a type belonging to the class of Polypi.—And various species are represented here; among them are stems, branching and supporting soft little animals, which come out like flowers.

The variety of these beings is such that indeed they rival, by their glorious colors and variety of form, the most brilliant flowers of the dry land.—Such as this Actinia are common on these shores, and have also universally been considered as Polypi ever since these beings have been combined into one class, and have been separated from the vegetable kingdom.

It would carry me too far if I were to give now the full history of the knowledge successively acquired upon these animals, and to refer to those views of these beings which were entertained by naturalists at the time when some were supposed to be simple mineral concretions, and others were considered as marine flowering plants; the animals upon the stems being mistaken for flowers, and the stems compared to the stems of plants.

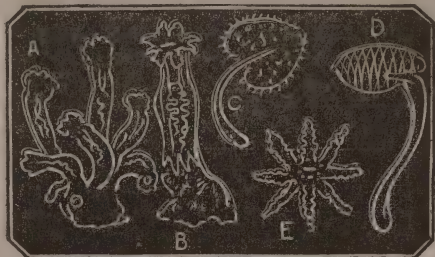
But after it was ascertained that there were contractions taking place in the soft parts, that there was an internal cavity into which food was introduced and digested, no doubt could remain as to the animal nature of these beings; and all small animals whose upper opening is surrounded by tentacles, and which are grouped together upon a common stem, were at once referred to that class. And some simple animals, like the Actinia, were also referred to the same class, being considered as isolated forms of the same character. But we see upon the following Plate (Plate XXXVI) one of these coral-like stems, (Retepora) with minute openings, in which numerous animals are contained, whose structure has been investigated by MM. Audouin and Milne-Edwards, and has been found to differ so materially from that of Polypi, that this type, of which there are various forms, is now generally considered as belonging to the great division of Mollusca, although they

[PLATE XXXVI—RETEPORE.]



are compound animals. All the investigations which have followed since this suggestion was first made, have only gone to confirm the view, that these porous animals do not belong to the class of Polypi, but to a higher type, and indeed resemble in some respects even the oysters, the clams, and still more the compound ascidiæ, in whose vicinity they will in all probability be placed forever, showing that compound animals may belong to all great groups of the animal kingdom, and even occur as anomalies among mammalia, in the shape of twins.

[PLATE XXXI—ALCYONIUM AND RENILLA.]



Other diagrams represent various other types. Here, (Pl. 30) for instance, the beautiful Tubulariæ are seen forming most beautiful flower-like animals uniting in bouquets upon the old logs and swimming lumber which are fastened in the water.

Two species of this kind are very common around the city of Boston. One (Plate XXX, fig. G) with a larger crown, occurs in great abundance upon the logs in Craigie's bathing house; another smaller species is found almost everywhere upon old logs. The larger is about two or three inches high, and the crown, when fully expanded, about one inch in diameter.

This diagram, (Plate XXXI, fig. A) represents another still undescribed species, with compound stems, from Boston harbor, belonging to the family of Alcyonium, in which every one of the individuals terminates with a star of eight fringed appendages or tentacles (fig. B). The most curious, however, is this one (fig. C), a Renilla, which I collected in Charleston, S. C.—an animal with a soft body of a hollow stem, sticking in the wet sand, with a large disc, spreading above which, seen from below, shows lateral dilations, from which, upon the upper surface, arise a great many

PLATE XXX—TUBULARIÆ.]



isolated little flower-like Polypes (fig. C), of which one is figured (fig. D) upon a larger scale, showing that the tentacles, eight in number, are also fringed like those *Alcyonium*, being regularly arranged in three pairs upon the two sides of the elongated mouth, a seventh and eighth tentacle being in the prolongation of the oral aperture. This animal is of a beautiful purplish color, emitting in the dark a most wonderful, soft, greenish-golden phosphorescent light.

There is another type of Polypi very common on the shores of Massachusetts and farther South, the *Actinia*, of which one species (*Actinia Marginata*, plate XX, D) is found upon logs along the wharves in Boston harbor and upon the rocks at Nahant, in great numbers. They are isolated animals, growing to a comparatively larger size than the other Polypi; remarkable for their extraordinary contractility, the body assuming constantly new forms and new positions; now entirely drawn out in the shape of an elongated tube with a circle of tentacles around the free extremity, (Fig. D) then the tentacles rising and falling, or shutting in and expanding; next shortened and contracted with the tentacles closed (Fig. E); or the external envelope entirely shut over the inner part, assuming then a hemispheric shape, like round tubercles sticking to the ground by their fleshy base. The variations of color are as numerous as the changes of form; upon the same spot may be seen brown ones, and others dark brown or blackish, yellowish, purple, salmon, rose-colored and more or less

mottled, the tentacles presenting alternations of dark and lighter rings, or at least having their tips differently colored than the lower part.

That *Velella* and *Porpita*, now generally arranged among Jelly fishes, will have to be removed from the class of *Acalephæ* and placed side by side with the *Actinia*, will not escape the attention of those who are familiar with these animals.

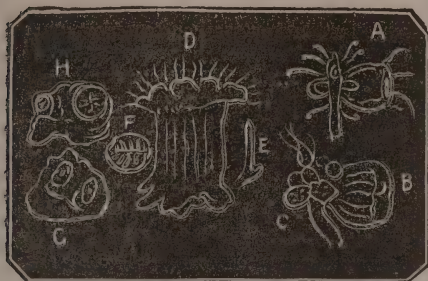
Recently, the Polypi have again been extensively investigated by Prof. Milne-Edwards, whose name is always to be mentioned when speaking of the lower animals, as scarcely any one has done more than he has in their investigation. Ehrenburg has also largely contributed to our knowledge of the Polypi. But no one has done more to illustrate their natural history than Mr. James Dana, of New Haven, Conn., who accompanied the exploring expedition under Capt. Wilkes, and who has published the most elaborate work upon this subject which has ever issued from the press. A work, indeed, which will remain a standard of authority in this department for many years to come.

The embryonic growth of these animals has been studied almost exclusively by Naturalists living in countries which have been wanting in facilities for investigation, and are deprived of privileges which Naturalists have enjoyed in other parts of the world, where the animal kingdom is more luxuriantly developed.

It is on the shores of Norway and Sweden that the most important investigations upon the embryonic growth of these animals have been made. There, where the observer is neither attracted by the variety of animals, nor by the possibility of discovering easily new species, the interest of the subject has drawn them into a deeper and more thorough channel of investigation, which has endowed science with a more extensive acquaintance with all the difference of structure which is shown by the animals of those shores. And, indeed, far from considering it an advantage to be placed upon a shore where new treasures are thrown abundantly into the hands of investigators, I think it is, on the contrary, an unhappy inducement for observers to devote their whole attention to the multiplication of specific distinctions, without allowing time for the more important and more extensive investigation of the physiological phenomena attending the life—attending the development of those beings.

The structure of the Polypi can be best exemplified in the *Actinia* (Plate XX, fig. D) as they are among the largest, and as they are now more extensively illustrated than any other type of the class has been before. And what I have to say of these animals will be scarcely more than a repetition of what Dr. Jeffries Wyman has published in the work of Mr. Dana, already mentioned; some few observations only, the result of my own investigations, having been added to his, since the publication of that work. The body is of rather large size for a Polype, measuring from

[PLATE XX—POLYPI ACTINIE, CORYNÆ, SYN-CORYNÆ, PODOCORANÆ.]



one to several inches in length when fully expanded; it consists of a membranous sac, as in all Polyphi, with numerous tentacles round the upper extremity, and contains within, another sac, opening above between the several rows of tentacles.

[PLATE XXXII—POLYPI—ACTINIE.]



In this drawing (Plate XXXII, fig. B) you notice the whole structure in a vertical section of the animal, in which the relations between the different parts and their interior cavities are at once seen. You notice the external walls of the animal, and the rows of tentacles forming the upper outline. And from the centre, where there is a large opening which must be considered as the mouth, hangs down a thin sac, suspended within the cavity formed by the external arms and the surrounding thick envelop of the body.

This sac is a stomach; it is maintained in its position by internal radiating membranes, extending all around the mouth and stomach and uniting with the external envelop so as to divide the intervening space into many chambers. There are also shorter folds which penetrate from the external walls towards the centre, so that the space between the stomach and the lateral walls is not one continuous cavity, nor uniformly divided into equal chambers, but it is a cavity divided and subdivided into wider and narrower spaces by partitions which extend either entirely across the cavity surrounding the stomach, or only partly into it, thus forming imperfect chambers; all the them, however, remaining connected by the open space which is left free of divisions below the stomach. Here is a diagram [Plate XXXII fig. A.] in which the animal is represented as divided horizontally, and in this horizontal section you see the cavity of the stomach forming one great whole in the centre and the partitions which extend from the external

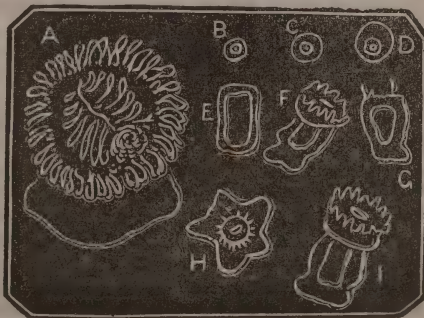
walls towards the centre either reaching the walls of the stomach or not, from the intervening septa. But these are not all equal. There are some of the partitions which reach half way towards the stomach—others which reach two-thirds of the way—and others still which reach most of the distance. Below [Plate XXXII fig. B.] we see them as they present themselves upon a vertical cut. From the external surface something of those partitions is already seen. The vertical striæ noticed [Plate XX fig. D.] are the external points of attachment of the fleshy partitions upon the external envelop of the whole body, and they extend high up into the margin from which the tentacles arise. And indeed on close examination it will be seen that one tentacle arises always between two partitions; so that a tentacle is, as it were, a radiating prolongation of the main cavity of the body, extending like the finger of a glove from each of the divided spaces upwards. You see this [Plate XXXII fig. B.] where the tentacles show plainly their connection with the main cavity, and where the divisions are as numerous as the tentacles.

These partitions are muscular fibres, and by their contractions they can shorten the animal. Suppose these vertical partitions to be at once contracted, the animal, instead of forming a vertical cylinder, becomes depressed. [Plate XX fig. E.] And as there are muscular fibres around the whole body, the tentacles can be drawn in, and the upper fibres, contracting more and more, may entirely conceal the tentacles and form such hemi-spherical bodies as are observed in these diagrams.—[Plate XX fig. G.]

Between these partitions, by very careful investigation, small holes can be discovered, arranged in vertical series (fig. D). The use of these tubes is not yet fully ascertained. I shall have an opportunity to refer to them again.

But I would mention, further, that the mouth (Plate XX, fig. F) is not a simple circular hole on the summit of the animal, but presents lateral folds upon a longitudinal fissure. At first sight, when seen from above, the inner membrane of the Actinia stretched between the tentacles seems to form a circular mouth (Plate XXXIII, fig. A); but on close examination, it will be noticed that it is

[PLATE XXXIII.—POLYPI—YOUNG ACTINIE.]



really a longitudinal fissure with lateral folds. All the tentacles terminate with a hole; they also constitute muscular tubes, with longitudinal and circular fibres, by the contraction of which they are alternately drawn in and out. The stomach, like the tentacles, empties into the main cavity of the body (Plate XXXII, fig. B), so that when the *Actinia* swallows its food, the results of the digestion are thrown into this common cavity, and there circulates by the agency of vibrating cilia between the partitions and in the hollow tentacles, until absorbed by the surfaces in contact. You see, also, in that diagram, that water can be introduced into the inner cavity through the mouth and the stomach, as well as through every tentacle, and also thrown out through stomach and mouth, and through every tentacle. The body is thus swollen by the water pumped through the suckers, or by that swallowed through the mouth. When the animal re-opens its mouth to throw out water, the undigested remains of the food are also expelled.

When the animal comes out from its contracted position, we see the suckers gradually expanding, (Plate XX, fig. E) and these numerous tentacles pumping water, and the animal successively swelling into its various movable changing forms. The existence of eyes in *Polypi* has been mentioned by Mr. Quatrefages. I have observed them in a new species of *Lucernaria* discovered upon the beach at Chelsea. In addition to these structures there is hanging from the partitions of the main cavity, [Plate XXXII, fig. B.] below the stomach, a series of bunches of eggs—ovaries, below those lower muscular partitions. All *Polypi* seem to have a structure similar to this. Those which do not resemble these in structure, are the types which I consider not to belong strictly to the class of *Polypi*. When the eggs of *Actinia* are matured, they are let out through the mouth. I have had an opportunity to see this myself. These bunches of eggs are freed in the main cavity of the body, and then through the lower opening of the stomach pressed into that cavity and finally discharged from the mouth, as represented in this figure. [Plate XXXIII, fig. A.]

They are sometimes entangled in the cavities of the tentacles, and have even been reported by Sir John Dalyell to be discharged from the tentacles. The young egg of the *Actinia* presents the structure which we observe universally throughout the whole animal kingdom. They consist of a mass of yolk substance, enclosed in a special membrane (Plate XXXIII, fig. B). Within is a germinative vesicle, and in the centre a germinative dot (fig. C). These yolks will grow (fig. D), the germinative vesicles and dots will disappear, and the germ being formed in the shape of spheroidal bodies, with a darker mass in the centre, will be hatched, and form a more elongated body, (fig. E)—the yolk being more distinctly separated from the animal layer proper, which is the external crust of the germ.—Above, a depression is formed; the lower part

is attached upon the soil, and around the upper depression, (Plate XXXIII, fig. F.) there are little protuberances formed, (Fig. G.) the central depression growing deeper, and the mouth is finally produced, surrounded by tentacles. (Fig. H.) But the most remarkable feature which I have observed in this development, is that the young *Actinia* differ from the old ones, in having at first only a few external tentacles; and these few are arranged in a very peculiar manner. Suppose this to be the first indication of the mouth; there will soon be surrounding tentacles, (Plate XXXIII, fig. H.) at first only five, though in the full grown animal there will be hundreds. Next there will be others, coming out between the first ones, so that soon ten are formed. Then there are everywhere in the intervening spaces more coming out, so that twenty will occur; and in this way the number is gradually increased. But the position of the primitive five ones has a relation to the longitudinal form of the mouth; one of the five primitive ones being always in the same diameter of the animal as the longitudinal fissure of the mouth. (Plate XXXIII, fig. A.) But the other four are in pairs.

After I had made this observation, I asked Mr. Dana whether he had observed such a symmetry in the arrangement of the tentacles. He stated that he had; and that in addition, one of the tentacles was sometimes different in color from the others. What this means I shall soon show when comparing the *Polypi* with the other radiated animals.

But now there are other *Polypi* whose embryology has been extensively studied. I mean the *Corynæ* (Plate XX, fig. C.) *Syncorynæ* (Fig. A.) and *Podocorynæ*, (Fig. B.) upon which Loven, Sars, Steerstrup, R. Wagner, and others, have made most remarkable observations. And also the *Campanularia Tubularia*, upon which we are indebted to Loven and Von Berend, and others, for extensive information. The *Corynæ*, and alike types are so closely related to the *Tubulariæ*, that the resemblance has been particularly noticed. And this close resemblance alluded to as a sufficient ground to leave the club-shaped *Polypi* with *Medusa*-like buds among *Polypi*, notwithstanding the great difference which has been noticed, both in their structure and mode of development.

Here we have the *Podocorynæ* (Plate XX, fig. B), and here (Fig. C) the *Syncorynæ*, which are small *Polypi*. The existence in Boston harbor of similar *Polypi* of the genus *Corynæ*, first described from the Northern shores of Europe, I have ascertained last year, and indeed there is a vast field to explore on these shores, as during a cruise on the South Shoals with Capt. Davis, in 1847, I have ascertained the existence of not less than seventeen species of this family, among which there are types of new genera, which I shall describe on another occasion. From the upper part of the stem of these *Corynoid Polypes* there are hanging down several little bell-shaped bodies, of a quad-

angular form. The outline of these bell-shaped bodies being, when seen from below, as in figures A and B. The angles are prominent, and from them there are colored specks rising, similar to the eye specks of common *Medusæ*. A membrane is stretched across over the central cavity, leaving, however, an opening below; and from the corners are produced short tentacles, which, in the progress of time, grow longer and more moveable. In the interior there is a sucker-like projection, first with a single margin, which will be fringed afterwards. From these details it is plain that these buds, when fully developed, resemble most remarkably the small *Medusa*, (Plate XXVIII, fig. C) to which I have before referred.

Indeed, they are finally freed from the stem upon which they grow, and move as independent animals.

The structure of these small animals is indeed very simple; as they have only four straight tubes branching in four directions from their summit.—The investigators of these phenomena have been unwilling to refer them to the class of *Medusæ*, but have considered them as closely allied to *Tubulariæ*, and belonging therefore to the class of *Polypi*. They have compared the *Medusa*-like buds of *Coryne*, *Syncoryne* and *Podocoryne*, (Plate XX,) to the crown of the *Tubulariæ*, (Plate XXX, fig. A.) and you see that the comparison is very close. You see that the hollow tube within the *Medusa*-like bud (Plate XX, fig. A.) will compare to the hollow cavity with fringes hanging below the tentacles of *Tubulariæ*. (Plate XXX, fig. A.) Then you see the tentacles above spreading around the bunches of eggs and arising from the upper cavity, as the main cavity of the little *Medusa*-like buds surrounds its inner hollow tube, from which the eggs are developed in them, forming also special bunches, exterior to the inferior or anterior part of the alimentary canal, so that the resemblances between these bell-shaped bulbs (Plate XX, fig. F) and the crown of *Tubulariæ* (Plate XXX, fig. A) is as close as it can be. The conclusion derived by Steerstrup from these facts is that the genera *Syncoryne*, *Coryne* and *Podocoryne*, (Plate XX, figs. A, B, C) should no longer be considered as genera by themselves, but only as the nurses of animals of a higher order, the little *Medusa*-like animal, but that they nevertheless should remain with the *Polypi* near the *Tubulariæ*. Steerstrup insists upon this point, when he says: "The more perfect forms, however, notwithstanding their resemblance to *Medusæ*, must still occupy the systematic place of the clariform *Polypes*, or *Coryne*, as animals closely allied to *Tubulariæ*, *Sertularia*, &c. &c."

Let us now examine the *Tubulariæ* and also the *Campanulariæ*, as they have been carefully studied, and then we shall be prepared for an opinion upon these conclusions. We have here [Plate XXVIII] a stem of the *Campanulariæ*, which has branches of various kinds. How these branches grow must be examined more fully.

[PLATE XXVIII—CAMPANULARIÆ.]



In a growing stem—the first origin of the stem we shall examine afterwards—there is in the interior a cavity, which cavity expands above and forms a kind of stomach; the moveable part of the animal forming tentacles around, and the mouth being therefore above. And from the side of such a *Polype* there will be, after a certain time, a bud, forming a simple sac, communicating with the main cavity, and the changes which have produced the main stem will be repeated here so as to give rise to another *Polype* of the same structure as the terminal one, with an open communication with its main cavity; and after by repeated budding, numerous branches, all alike, have been found as they are figured in this diagram, [Plate XXVIII] Where you see seven buds all alike, some new buds forming in the axis between the main stem and the first buds. And these new buds differ from the former, inasmuch as the bud will not terminate with a new *Polype*, similar to those of the first buds, but will remain closed, and while it is still closed there may be buds arising on its side in which eggs are developed.

Loven, who described these phenomena more extensively, represents these axillary buds as giving rise, by budding, to new branches, remaining longer shut in a common cavity, and indeed being branches similar to the external one; with the only differences that the terminating animals have smaller tentacles, and are of a slightly different shape; communicating with the main cavity, and giving finally rise to free moving individuals; whilst there are below simpler sacs, of the same order, but still less developed. Plate XXXV represents the various stages of this growth.

Now these sacs are something like buds; but they are, in fact, eggs, which, in the beginning, are simple buds, or diverticula from the common cavity, so that we can consider the whole as buds, which throw out new buds, from which eggs are developed, in the shape of pouches. And that these are eggs, can be proved by the characters which distinguish eggs. (Pl. XXXV, fig. D.) They may have a germinative vesicle, and a germinative dot; and there a new animal is formed, which will escape as soon as the upper buds, which are now full grown, have removed the closing operculum; so that, by a process of budding—of budding egg-like buds—there is a new generation, formed, which does not remain upon the primitive stem, but is freed; and when freed, the germs arising from the eggs are elongated, and little cylindrical animals, which swim free, appear; and

[PLATE XXXV—BUDDING OF CAMPANULARIA.]



after having continued free for a certain time, they become attached, and then the whole mass is depressed and enlarged into a disc-like body, the centre of which is somewhat prominent; rises then more and more, and begins to be transformed into a little stem; and this little stem will open above, and form a termination, like that of the common buds of *Campanularia* (Plate XXVIII.) that is to say, an animal with an internal cavity.—We have thus again a beginning of one of those complicated stems, which, by the multiplication of their buds, form communities of animals, of two kinds, viz: such as are individuals similar to the animal at the end of the main stem, and others from which a free generation is produced, and which, after remaining free for a certain time, go on to repeat the same process of branching and budding.

In the *Tubularia* (Plate XXX, fig. A) we have a similar growth. One of these bunches of eggs, when examined in its immature condition—in its earliest formation, (Plate XXX, fig. F)—is simply a branch with lateral buds, and the digestive cavity communicates freely with all these little buds. But their interior mass assumes gradually a more rounded form, and is successively enclosed in the external mass, which will enlarge, and then there will be finally isolated eggs developed, in the form of bunches, when upon the summit of every one of them a distinct animal envelop is formed, which extends downwards upon the yolk—as the

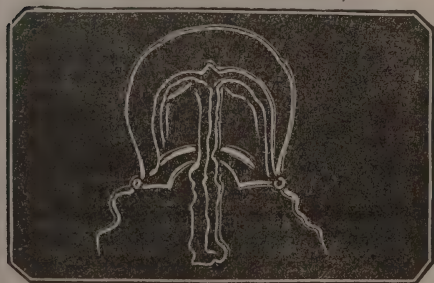
internal mass can be considered as a yolk—and after it has grown so as to appear like a cup, with tentacle-like appendages, the little animal is freed, and has a structure like the young *Medusa*, as it is figured from a *Campanularia*, in Plate XXXV, figures T, P and Q. The whole process of budding in this animal is shown in figures A, B, C, &c., (Plate XXXV)—first, the changes which regular common buds undergo in their development, and next, (Fig. E to G), the changes of the eggs proper, with their animal envelop surrounding the yolk, and finally dividing into tentacle-like appendages below. The internal cavity being formed by the changes which the remnant of the yolk undergoes. The young animals which are derived in this way in *Tubularia* and *Campanularia*, from egg bunches, are so similar to the free buds from *Corynæ*, *Podocorynæ* and *Syncorynæ*, (Plate XX, figures A, B and C), that their analogy cannot be mistaken. This resemblance can even be recognized in stages of growth not further advanced than these, (Plate XXXV, figs. T, P, Q). Some *Medusæ* occurring on these shores—for instance the genus *Stomabrachium*—have a very close resemblance to those germs of the *Campanularia* (Plate XXVIII), and *Medusæ*, with only four arms and four tubes diverging from the central cavity, with fringes all round: and I should not be surprised at all, if *Stomabrachium* was finally found to be the free *Medusæ*-like generation of *Campanularia*. But now as the affinity between all these *Polypi* (Plate XX, XXVIII and XXXV) and the *Tubularia* (Plate XXX) is very clearly shown, and as on that account these animals are all considered as belonging to the class of *Polypi*, though they give rise to animals so closely allied to *Medusæ*, the question arises how far *Tubularia* itself can be considered as strictly belonging to the class of *Polypi*, or whether it would not be more natural to view it as a type of *Medusæ*, furnished with a permanent stem.

The only objection to this is, that true *Medusæ* are not formed in the same way as *Medusæ* like free buds of *Corynæ*, *Podocorynæ* and *Syncorynæ* (Plate XX.) These have arisen from buds growing upon *Polypi*-like stems, though they are finally *Medusæ*-like animals; whilst true *Medusæ* are multiplied by transverse division of *Polypi*-like stems, which can have no influence upon our appreciation of their real structure; so that the question properly is, whether there can be real *Medusæ* with a stem, or not. We have, therefore, in this stage of the investigation, before deciding one way or another, to compare the true *Medusæ* (Plate XXXVII and Plate XXVIII, fig. C) with those *Polypi*, the *Tubularia*, (Plate XXX), when it will be seen that their structure agrees in every respect but that one, that the *Tubularia*, with its crown, rests upon a stem, whilst *Medusæ* proper are entirely free. The great difference there seems to be in the forms of these animals is more apparent than real, the cavity which hangs below the ten-

tacles corresponding to the central alimentary tube of the Medusæ, which is only drawn in between the gelatinous walls of the disc, though it remains equally free as in Tubularia. The upper cavity of Tubularia answers to the disc of Medusæ proper with its cavities; and in both the ovaries are outside of the alimentary cavity, as well as of the main cavity of the body. Indeed, the agreement is perfect in every respect, and we must come to the conclusion that from their structure Medusæ and Tubulariæ must belong to the same class, Tubularia being Medusæ with a stem, and bearing the same relation to free Medusæ, as crinoids bear to free starfishes. And so we have in the class of Medusæ attached types, as well as in that of Echinoderms, and in that of Polypi.

In a more general point of view, we may, however, compare further, all radiated animals, when we shall find that they really constitute a natural, well circumscribed group in the animal kingdom agreeing in all important points of their structure being strictly constructed upon the same plan, although the three classes which we refer to this great department differ in the manner in which the plan is carried out. In the first place, I may mention that besides Polypi, Medusæ and Echinoderms, the other classes which were referred to the type of Radiata, have been removed from it, or are to be removed from this connection. The intestinal worms indeed are truly articulated animals in their fundamental plan of structure, and have to be connected with the worms proper, while the Infusoria, Polygastrica and Rotatoria are very heterogeneous classes, the latter of which has to be united with the Crustacea and the so-called Polygastrica, to be divided off according to their various structures, some being germs of aquatic plants, and others the first stages of growth of various worms, as I have ascertained by direct observation. As for the classes of Polypi, Medusæ and Echinoderms, if we bring together the diagrams (Plate XXXII) representing an Actinia in a vertical section, with that of Plate XXXVII, which represents a similar section of a Medusæ,

[PLATE XXXVII—MEDUSA.]



and other illustrations of Echinoderms exhibited in a former lecture, and the vertical section of an Echinarachnius, we shall have the elements (Plate XXXVIII, fig. E) of a closer comparison between the three classes. If we were indeed to in-

vert the Polype and place it with the mouth downwards, as it is naturally in free Medusæ, we could see at once that in the Polypus we

[PLATE XXXVIII—ECHINARACHNIUS.]



have the same general arrangement as in the Medusæ. There being a separate alimentary cavity and a common cavity of the body only in Medusæ, (Plate XXXVII) the anterior part of the alimentary cavity hangs down with the mouth freely from the walls of the body. This part of the alimentary canal answers to the cavity of Actinia (Plate XXXII, fig. B) which is called stomach, and from the upper part of the Actinia, in its inverted position, arise those partitions which end in tentacles answering to the disc of Medusæ, with its cavity, branching into similar tentacles.

We have also again a common cavity in Medusæ (Plate XXXVII), as well as in Actinia, only more circumscribed, and branching off into tubes which communicates in similar manner with the tentacles, so that the general arrangement is perfectly identical. The difference is, however, this—that in Medusæ the tubes arising from the central cavity are circumscribed, while in the Actiniæ (Plate XXXII, fig. B) they are only partitions communicating all together. And in the Medusæ (Plate XXXVII) there is a distinct nervous system. I suspect that in Polypos we should find the nervous system in the same position as a ring round the mouth, if it is at all distinct in those animals; that however eye-like specks have been noticed, even in these lowest animals, I have already mentioned.

As for the ovaries of the Medusæ (Plate XXXVII),

they arise externally from the lower or central cavities of the alimentary canal, and are surrounded by the disc, which contains the main cavity of the body, and from the periphery of which the tentacles hang down, so that here the ovaries are outside of the stomach, and outside of the main cavity, as in *Tubularia*,—and not within the common cavity, as in *Polypi*.

Now in order to insist more strongly upon the fundamental differences which exist between *Polypi* and *Medusæ*, even if we include *Tubulariæ* among the latter, let me once more call your attention to the *Tubularia* (Plate XXX, fig. A). We have here a mouth, with the anterior alimentary cavity, which will assume all possible shapes, as we see in these various diagrams, hanging outside of the common cavity, and not within it, as in *Polypi*. We see those bunches of eggs, arising below the tentacles, between the tentacles and the anterior alimentary cavity, also outside of the alimentary cavity, the central cavity extending above, so that the analogy is perfect in every respect.

And as we have in the *Corynæ*, *Syncorynæ* and *Podocorynæ* buds, which, though growing from *Polype*-like animals, will produce real *Medusæ*, their close resemblance to *Tubulariæ* will only be an additional evidence that these must be referred to the class of Jelly-fishes, and that the club-shaped *Polypi*, in their perfect condition, are also *Medusæ*, and that their earlier stages of growth are only nurses to produce real *Medusæ* by alternate generation. The *Tubulariæ* themselves will have, however, to be considered as the lowest type of *Medusæ*, preserving something of the *Polype* structure, as they are for life provided with a stem, from which the crown hangs down. And from this stem would arise buds similar to the terminal animal (Plate XXX, fig. G) which would remain connected with the stem, thus forming branched compound *Medusæ*. And if this ground be correct, not only *Tubularia*, but also *Campanularia* and *Sertularia* shall be united with *Corynæ*, *Syncorynæ* and *Podocorynæ* in the class of *Medusæ*. Thus circumscribed, the class of *Medusæ* would present the most remarkable parallelism with the class of *Echinoderms* and that of *Polypi*, in both of which there are free types and such as rest upon attached stems, a parallelism upon which Oker has already insisted, in a general way, is his classification of the animal kingdom.

To investigate further this subject, there is a rich field in this vicinity, where animals, *Tubularia*, *Campanularia* and *Sertularia*, occur all around the shores of Massachusetts.

Again, if my conjecture of the necessity of combining these *Tubularia* with *Medusa* is correct, I venture to foretell, that among those small species of this class, which are found on this shore, we have the *Medusa*-like form of the *Coryna*, in the little *Oceania* of Dr. Gould's Report, whose structure is illustrated in Plate XXVIII, fig. C., as I have

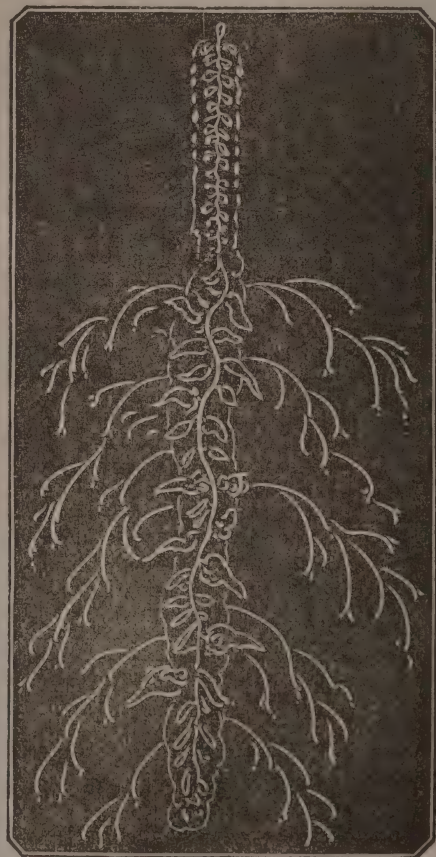
ascertained by dredging, that *Coryna* occurs in Boston and harbor.

That *Coryna* has been found so seldom is because it lives in deep water, and is not discovered unless by dredging.

I should not be surprised at all to find also *Stomabrachium*, as the *Medusa*-form of *Campanularia*, which occur all over the shores of this continent, and that *Bongainvillia* could be the *Medusa* of *Tubularia*, if they produce at all a free generation, seems to be probable, when we consider the form of its crown. (Plate XXX., fig. A.)

As for the gradation of types in the class of *Medusa*, we should consider the *Tubulariæ* as the lowest, for the reasons already stated. Next we should place the free compound *Medusæ*, the *Physophoræ* of Eschscholtz, which correspond to the next stage of growth of *Medusa*, known under the name of *Strobila*.

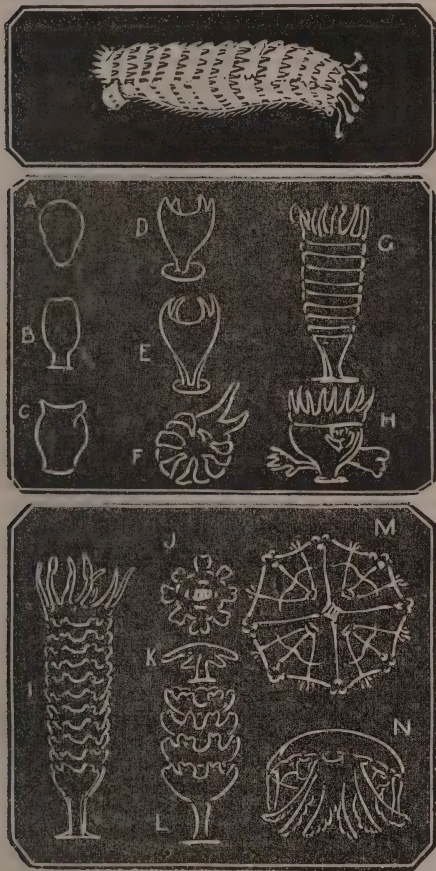
[PLATE XXVI—MEDUSA.]



Next we should place the free *Medusæ* or *Disco-phora* of Eschscholtz, and highest the *Ctenophoræ*, as by their comb-like rows of fringes, which may be considered as a lower form of *Ambulacra*, they

come nearest to the Echinoderms. This arrangement, which is natural in itself, would show the most admirable agreement between classification and the phases of embryonic growth in this class, and also because they come nearest to the first stage of growth of the common Medusa. [Plate XIV and XIX]

[SEE PLATES XIV LECTURE 3, AND XIX LECTURE 4]



The analogy again between Medusæ and Echinoderms is too easily ascertained to be ever mistaken by any one who attempts to compare them in the same close manner. The chief difference here consists in the more developed inner structure of Echinoderms, whose organs are more diversified and isolated, and in the harder coverings which protect the soft parts, besides the addition of some special apparatus which do not occur in the two lower classes of Radiata.

The improvements which I anticipate in the class of Polypi are fewer, after removing the Retepora and allied types, to the great groups of Mollusca and the Tubulariæ to the class of Medusa. We shall only introduce the Porpita and Velella in the vicinity of Actinia, and then, as Mr. Dana has done,

divide the Polypi proper in Actinoids and Aegonoids, the former division embracing those with simple tentacles, as Actinia, (Plate XX fig. D.) the latter those with fringed tentacles as Alegorium and Renilla. (Plate XXXI.)

All the stone corals proper belong to the type of Actinia, and upon a close comparison of the structure of this animal with the ancient fossil Cyathophyllum-like Polypi of palæozoic rocks, some further hints may be derived as to the order of succession of Polypi in geological times, which is at present very little understood. How the calcareous stem is formed in Polyps, can be perhaps nowhere better studied than in the little Alcyonium (Plate XXXI, figs. A, B,) of Boston harbor, where calcareous nets and spicules are deposited in regular groups below and within the base of the tentacles, and at the opposite extremities of the animal, between which the muscular fibres are attached.—There is, moreover, a peculiarity in the structure of Polypi, which can be easily observed in the Ranella. (Plate XXXI, fig. E.) In this Polype the mouth has an elongated form, and there is one tentacle in advance and one behind this opening, in the longitudinal diameter of that fissure.

Under the form of radiated animals we have, indeed, through the classes of Echinoderms, Medusæ and Polypi, every where indications of a bilateral symmetry, concealed under the more prominent outlines of a radiated arrangement of the parts.—We have really among Radiata the first indications of the general bilateral symmetry which prevails universally throughout the animal kingdom, even in the class of Polypi. (Plate XXXIII, fig. A.) In Actinia, the lowest condition, this bilateral symmetry is noticed in the longitudinal direction of the mouth, (Plate XX, fig. F) and in the arrangement of the first formed tentacles, of which one is seen always in the same diameter with the mouth, whilst the other tentacles are placed in two pairs on each side, (Plate XXXIII, fig. H) which is peculiar in such species. We have also indications of a bilateral arrangement in those Medusæ in which the body is compressed laterally and more or less oblong, as in Beroë, Cestum, &c. where one diameter is much longer than the other. We have it still further in the division of the tentacles hanging down from the mouth in the common Medusæ, in which there is frequently one tentacle more developed than the others. That Echinoderms are regularly bilateral under their spherical forms, I have already shown, fifteen years ago, when I first ascertained that the Madreporia bodies lie always symmetrically between two of their rays in the longitudinal axis, which is parallel to the direction of the alimentary canal, as it extends towards the elongated extremities of the higher types of that class.

Another peculiar arrangement which is common to the Radiata, is the existence of water tubes, establishing a permanent connexion between the surrounding element and the internal cavity of the body. In the Medusæ (Plate XXVII, figs. A

and B), I have already shown the structure by which the water is introduced into the cavity. In the Echinoderms is figured this arrangement in the star-fishes (Plate XXXVIII, fig. D).

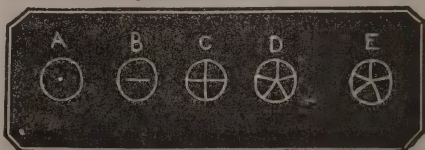
Through these almost microscopic tubes the main cavity is constantly filled with water, which escapes freely from the star-fishes when they are taken out of the water. They should not be mistaken for ambulacral tubes, which are placed in regular rows—whilst the water tubes are scattered almost over the whole surface of the animal, but only seen when fully expanded in the living animal. In the Actinia, the water system is plainly developed (Plate XX, fig. D), in the forms of minute pores arranged in vertical series.

From the above statements it can be concluded, that there is the strictest agreement between all Radiata in the general plan of their structure; and this analogy can even be traced in the embryonic growth—all the Radiata beginning by the formation of a distinct layer round the yolk in the form of a spherical crust, from which the more animated parts are derived, whilst the alimentary cavity is formed by the modification of the central mass of yolk. In addition to this regular mode of reproduction, the Polypi and Medusæ are also multiplied by buds, and some of the Medusæ by a peculiar modification of the alternate generation—new individuals being formed by the transverse division of a primitively simple stem. Whether anything like an alternate generation takes place in the class of Echinoderms, remains still doubtful; but I cannot help thinking that the Pedicellariæ are the last indications of a kind of budding, giving rise to very low organisms, which can only be compared to the peculiar beak-like buds of some of the Sertulariæ. This uniformity of structure and growth calls for an additional remark. Ever since the natural and physical sciences of graphical representations have been introduced, progress has been made much more rapidly than before.

As soon as Humboldt had drawn his isothermal lines, investigations in all parts of the globe were at once called for. And so it was in chemistry, when the formulæ were introduced to represent chemical composition, by which an insight into the constitution of numerous bodies could be obtained at one single look. Now in the animal kingdom nothing has yet been done to represent by symbols either structures or natural affinities; only the teeth of Mammalia are noticed in a regular system. Something, however, has been done, and is extensively introduced in Botany, to represent the arrangement of the leaves of plants and the parts of the flowers, by formulæ. But to represent structures—to represent affinities by symbols is an attempt which has not yet been made, and which I think could now be satisfactorily introduced. Only general symbols for the main groups of the animal kingdom, representing their fundamental embryological character, have been introduced into the text book which I have published in connection

with Dr. Gould, where a star was used to represent the Radiata, where Mollusca when represented by an inverted Greek W, Articulata by a W, and Vertebrata by the figure 8, these diagrams having reference to the peculiar mode of development and of the germ. That the Radiata is best represented by a circle, is shown by what I have said of the first formation of the germ, which surrounds the yolk entirely from beginning, and forms, as it were, an animal crust round the yolk, so that we could have, instead of a star to represent Radiata, any general simple circular outlines with a dot in the centre, to remember the analogy of their general structure with that of the eggs, with the lowest condition of all animals.

[PLATE XXXIX]



But when we would like to represent special classes, either, Polypi, Medusæ or Echinoderms, I would propose that instead of a dot, we should have for the Polypi a longitudinal line across the circle. (Fig. B.) indicating the first appearance of a bilateral arrangement under the form of a spherical circle. To represent the Madusæ, I would propose a circle with a cross within, (Fig. C.) to indicate that in these animals there is a radiation of branching tubes from the central cavity. And to represent Echinoderms, I would have a star in the circle, (Fig. D.) corresponding to the form which is the most characteristic of that class.

So that the three classes of Radiata would be represented by their peculiar figures, and by the addition of a single letter to these symbols, we might at once represent either of their families—for instance, having the diagram of Echinoderms, an additional C would represent Crinoids, E would indicate Echini, and A would represent Asteriæ (Fig. E).

And how important this would be, is at once obvious, if we look at geological works, where the lists of fossils, simply mentioned by their names, do not convey any idea to the reader. But if, instead of Saccocoma, shortly we append the figure of Echinoderms, and add a C, we should know at first sight that this is a fossil of the class of Echinoderms belonging to the family of Crinoids, and the symbol itself would at once remind us of the peculiar structure of these animals. Those great figures being used to indicate the families, an additional small letter might indicate minor divisions, and so on; so that these symbols would show all the affinity of any given animal, and form in reality a complete picture of the various relations which exist among all animals.

In my next Lecture, I shall enter into the department of articulated animals.

LECTURE VI.

I now proceed to examine the great group of the animal kingdom, which Naturalists have designated under the name of Articulata. These animals are remarkable for one peculiar feature of their structure; the body consisting of a series of joints moveable upon each other, to which are frequently added moveable appendages, sometimes subdivided into joints, which are moveable also. This is the common character of all Articulata, and upon Plates IV, V, VI, VII, IX, X and XI you see various forms of this great type.

[PLATE IV—RAT-TAILED WORMS]



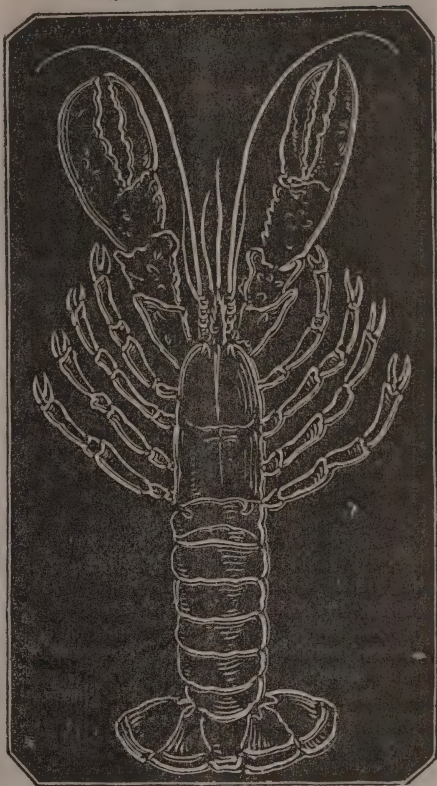
The Articulata have been divided into three classes: *Crustacea*, as crabs, lobsters and all the animals like them; *Insects*, as butterflies, beetles, flies; and *Worms*, the worms which live free in the water or in the soil, and also the parasitic and intestinal worms.

These three classes differ in their structure as well as in their general form, and they have been placed in our systematic works in an order which deserves particularly to attract our attention.

The Crustacea are placed highest in the series of Articulata, and the Worms lowest; and between them, the Insects, so numerous and so exceedingly diversified. In the opinion of Naturalists, this order of succession agrees with the complication in structure of these animals. And they insist upon this order as really indicating the natural gradation among them; the Crustacea being considered highest, owing to the perfect development of a heart and a regular circulation, and also owing to the concentration of the nervous system and the combination of its elements. The want of a regular circulation in the Insects has been the reason why they have been placed in the second rank. The Worms, from the uniformity and number of their rings, to which are attached feet-like appendages almost as numerous as the rings themselves, have been considered as the lowest.

Now in this order of succession, to which Naturalists have specially devoted their attention, which they have investigated with particular reference to a natural classification, I think we have

[[PLATE VI—LOBSTER]]

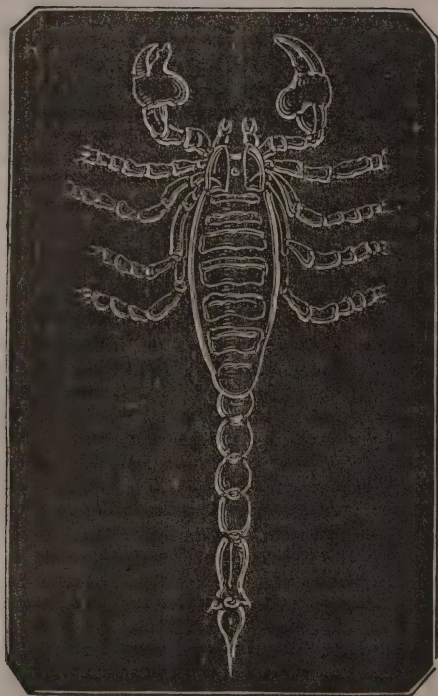


another instance of a mistaken view of the subject, derived from a mistaken estimation of anatomical characters. I am prepared to show that Crustacea are not the highest; that Insects should be placed at the head of Articulata; and that they are in every respect the highest. And after the grounds upon which I intend to place them highest have been illustrated, I expect it will be found that the anatomical structure agrees here again with the order which the metamorphoses actually indicate; and that it was a mistaken view of the complicated structure of the Crustacea which influenced Anatomists, and induced them to place Crustacea highest.

Before, however, I can go through this comparison, I must illustrate in detail the different classes of this great group; otherwise my comparisons and my grounds would scarcely be intelligible.

I shall devote this evening to the illustration of that one class which I consider as highest among

(PLATE VIII.—SCORPION.)



Articulata—that of Insects. And before beginning this investigation, I will simply mention that the group of Articulata, as it is now circumscribed, has not always been considered as containing only three classes. A great number of divisions and other arrangements were, at various periods, attempted by Naturalists. The Spiders, for instance, were considered as one entirely distinct class, placed between Crustacea and Insects, though I am of opinion that they are better united with the Insects, owing to their structure, as well as their natural development.

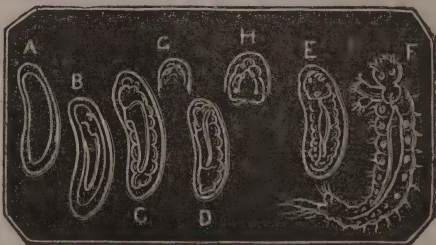
Among Articulata, groups have been introduced, which were formerly placed in other great divisions. For instance, the Barnacles were long considered as Shells, from their external coverings, which are really shells; but their anatomical structure has proved a relation between them and Articulate animals, and really a close relation to Crustacea proper—so close a relation to Crabs and Lobsters, that, at the present time, no Anatomist doubts that the Barnacles must be placed in one and the same class with them; though perhaps among Zoologists, there may be some who still think that the external form should be taken into consideration, and not overruled by the internal structure; but such doubts deserve scarcely any longer notice.

As I mentioned in the last lecture, intestinal worms were placed among Radiata, but they are proved to be Articulata, since the nervous system

has been lately discovered by Mr. Blanchard in all the principal types of intestinal worms, and found to agree, but with some modifications in its general arrangement, with that of Articulata. The Infusoria were also formerly arranged among the Radiata, but now their structure is more extensively known, they should be scattered and arranged among various classes, according to their inner organization and mode of growth—some belonging to the Worms, and being only the young, or embryonic condition of worms of Planariæ, for instance; others belonging to the vegetable kingdom, and being also embryonic conditions of various Algæ; and others still, belonging to the Crustacea, as for instance the Rotifers. It is remarkable that the extensive investigations made upon the Infusoria, the object of which was to illustrate the uniform structure of these animals as a class, go to show that the class ought to be broken up as a natural group, and distributed among various other classes.

How much remains to be done among the small organized beings, which have to be investigated by the microscope, will be at once understood when I mention that, for instance, the egg of the Mosquito-like animals whose embryonic changes are represented in Plate VII, figs. A. and F., was first considered as an Alga, and described as a species of *Gloeonema*, before it was found to be a Mosquito-like insect.

[PLATE VII.—EGGS OF MOSQUITOES.]



The great class of Insects is particularly remarkable for the metamorphoses which these animals undergo. And you may at once perceive how difficult it must be to trace all the changes of these animals when I mention, that the perfect being—the perfect insect may be an aerial animal, provided with wings, and flying about; when in another condition, it is quietly buried in the soil, immovable, not taking any food; or, in another condition, it is an aquatic worm, swimming freely in the water.

Under such circumstances, unless there is an opportunity to trace all these successive changes, you see how mistakes, as gross as the one to which I have alluded, may be made. Naturalists are now aware of the possibility of such mistakes, and do not consider an investigation as perfect, as long as the direct connection between the facts in any given case has not been ascertained by continuous observations. Articulata undergoing such extensive changes, must, therefore, be studied in many

more points of view, under more manifold aspects, than any other animals. And we have here to investigate external changes, as well as internal modifications of structures; changes of habits, as well as changes of forms; indeed all the successive transformations through which these animals gradually pass from their formation in the egg to their perfect condition.

The embryology of Insects proper has not been so extensively and so fully studied as the embryology of other classes. There is generally a great difficulty in examining the eggs of insects, owing to the opaque condition of the yolk-substance, the softness and transparency of the primitive germ, and the thickness of the horny envelope which surrounds the egg. You see under what difficult circumstances the observer is placed, to have to break up this hard crust without injuring the soft and delicate germ—which is, besides, exceedingly small,—and then to distinguish the various forms of their transparent body, resting upon a dark, opaque centre;—circumstances the most difficult for microscopic investigation which can be found. And so we have only a few species whose embryonic growth has been satisfactorily examined.

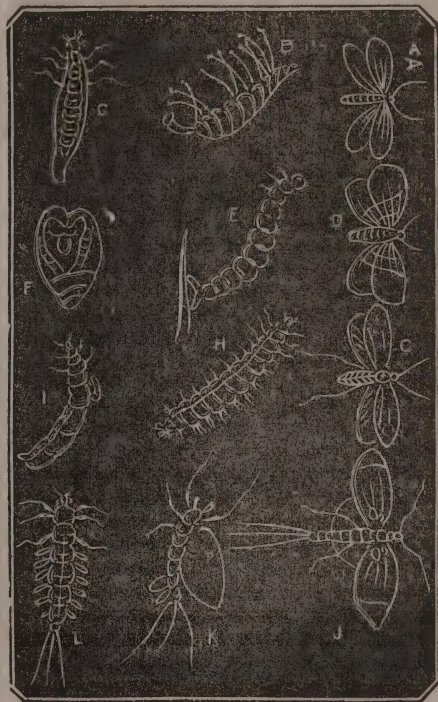
Professor Kolliker of Zurich, has made those investigations, and I introduce here, (Plate VII.) the diagrams which he has published of one of those series, in order to show how peculiar the mode of growth of insects is, and how different it is from the changes which other animals undergo within the egg.

After tracing those changes which take place within the egg, I shall proceed to allude to the changes which the Worm undergoes to form a perfect Insect. The egg itself consists universally among all insects, of a yolk of opaque substance, enclosed in a hard envelope. When the eggs are laid, there is no germinative vesicle, no germinative dot, seen within. The eggs have really undergone extensive changes before they are laid, and when laid, the envelope which surrounds them is already thick and opaque. In order to ascertain whether the egg has primitively the same structure as that of other animals throughout the animal kingdom, it is necessary to trace the formation of their substance back to the ovary, and examine the young egg, when the germinative vesicle, with the germinative dot, surrounded by a transparent mass of yolk, enclosed in a membrane, will be observed, as in all animals; and it is only shortly before the egg is laid that a thicker envelope is formed by the addition of layers of more consistent matter, which are successively deposited in the oviduct around the yolk membrane, to protect more effectually the eggs, which in so many insects have to pass the winter in that condition, before the caterpillar or worm is hatched. However, in the investigation of the formation of the egg and its envelopes, there remains much to be done in the class of Insects.

It is a peculiarity with the eggs of insects that

they remain a long time after they are laid, before undergoing their regular transformation; at least, this is the general impression. That, however, regular transformations begin in the winter, and go on during the cold season in this well-protected cuirass, has recently been ascertained by a gentleman of this city, Mr. Waldo I. Burnett, who is at present investigating successfully this difficult subject; so that the changes taking place in the eggs of various insects are likely to be soon supplied.

[PLATE X.—INSECTS WITH THEIR LARVÆ AND PUPÆ.]



The form of the eggs of Insects is exceedingly variable. There are eggs, for instance, which are attached to a long stem, (Plate X, fig. B) from which they hang down. That stem, however, belongs not to the egg proper, but is only a part of its external covering. The layers of protecting substance around the egg, are extended beyond the growth of the egg itself; and through these stems the eggs are attached to leaves of trees, resembling little fungi or cryptogamic plants, for which they have been sometimes mistaken. The first thing which takes place in the egg after the germinative dot and germinative vesicle are gone—after the yolk has become opaque, is the formation of a transparent layer of substance all around the yolk, as seen in Plate VII, fig. A, which represents the young animal, or germ, in its earliest condition. As soon as this animal coating has grown

sufficiently thick to assume definite outlines, a broad open space is noticed on one side of the germ, through which the yolk is very extensively seen. From further changes, it will be ascertained that the continuous mass represents the ventral portion of the animal, and that the free opening is on the dorsal side of the germ. At this earliest stage, some few changes of substance have already taken place. The animal layer, when first formed and examined under the microscope, is seen to consist of small cells, which have little dots within. At first, there is only one layer of such cells; then, a second layer is formed, probably derived from the substance of the yolk itself. Then there are three or four such layers, the cells being probably multiplied and increased in number by the bursting of the primitive cells, and by the growing into cells of their minute inner dots.

This seems the more probable, as with the increase of layers, the cells becoming more numerous, are also found to be smaller; so that, when there are four or five such layers, the cells are so minute as to require a higher power of the microscope to examine them; showing that these cells increase by evolution from the primitive ones. The appearance of a thick animal layer around the yolk, as the first indication of the germ, with a large open space opposite the main bulk of the embryo, is a peculiar feature of the mode of formation of insects, by which they differ widely from other animals. Here, (Plate VII, fig. B) the opening is towards one end of the egg, at which end we also notice upon one side of the germ, the first indication of a transverse division, marking out the head.—Next, (Plate VII, fig. C,) there will be some contractions taking place upon the longitudinal axis of the body, dividing the germ into several joints. The first change which takes place in the germ of an articulated animal is, therefore, an indication of the type to which it belongs. It is really an articulated animal before any further indications of a structure are introduced. The first division which takes place goes to indicate the position of the head. At this period, (Plate VII, fig. B), the yolk mass is already reduced to a smaller space. Next the transverse divisions appear, those of the head growing more complicated as represented in Plate VII, figs. C, G, H. And then, there is a well defined outline formed below the yolk, (Fig. D) extending to the anterior divisions of the germ, and towards its upper side, going to form the alimentary canal. The mass of the yolk is still more reduced, the membrane which now encloses it from below having folded itself upwards, so as to assume the shape of a little boat, (Fig. E.) and parcels of yolk remaining scattered on the sides. At this period we can already observe that the folds on the outside of the body will be transformed into joints. There is a head at the upper end of the germ, and at its lower side there are indications of legs (Fig. E). A wonderful arrangement is now plain, which was first discovered among Articulata by Herold,

in Spiders, and afterwards confirmed by Rathke in Crawfishes, namely, that in articulated animals the folding of the germ takes place in such a manner as to have the navel upon the back, that is to say, the opening by which the mass of yolk communicates with the alimentary cavity has a position strictly opposite to what is observed in other animals. The germ, indeed, folds itself around the yolk, leaving a broad opening on that side of the animal which, in its final structure, will be the back. (Plate VII, Fig. D.) The side opposite the navel being the one from whence the feet come out, and that where the opening is observed, being the side from which the wings will be developed. The membrane which was developed below the yolk has now folded itself more extensively upward, and forms an elongated open channel, which finally grows into a closed tube, the alimentary canal, as it is seen in the animal more fully developed (Fig. F), where there are some parts of the yolk remaining in the joints. Before the yolk has entirely disappeared, there is a pair of rudimentary feet developed in the anterior part of the embryo, which will disappear before this embryonic animal has the proper form of the larva to which it gives rise. There are also at the posterior extremity indications of false feet forming, and all along the various joints of the body, which have been successively marked. These are, however, not feet proper, but only stiff hairs.

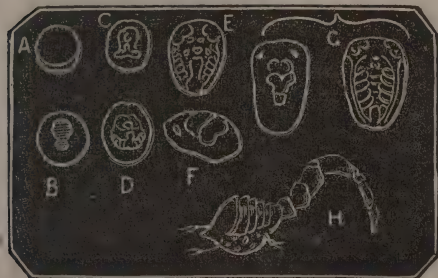
From the facts stated above, it is plain that in the class of Insects, after a complete investigation of the growth of the egg of one species, (and indeed of several species) it has been ascertained that the germ is not developed above the yolk, but below, as we have observed it in Radiata. There is not, as in Radiata, a cavity formed below, extending within the body to the stomach and the mouth; but we have in this case a germ which is forming below the yolk. Of course, such an egg could be reversed, and it might be said that there is no difference between the germ of Radiata and Insects—that we may just as well turn the egg of Insects so as to have the germ in the same apparent position in both cases. But if we turn in such a manner an egg of an insect, with its germ, we shall find the feet growing out of the upper side, and we shall find the opposite, or lower side, giving rise to a pair of wings. This would only show a reversed position of the whole; as we may place the feet of an Insect upwards, and the wings downwards, and have only an inverted Insect. But by thus changing the external position of the animal, the legs remaining opposite the wings, whether the navel be primitively open between the wings or above the animal, or vice versa, we shall not change the relation of its parts, in their growth. And so you see, that the articulated animals grow in a position the reverse to that of the Radiata, and undergo successive changes, which at a very early period give rise to those moveable joints which characterize Artic-

lata in general, and are seen in the lowest forms, as well as in the Lobsters (Plate VI), or Scorpions (Plate VIII), or any of the insects.

That this mode of growth is not peculiar to insects alone, but is characteristic of Articulata at large, follows, from the beautiful investigations of the embryonic growth of Crustacea and Spiders, which have been traced by many Naturalists, but above all by Herold, Rathke, Erdl, &c.

That the same mode of growth is also observed in Crustacea and Spiders, can be satisfactorily ascertained by a glance at plate III, where in a Shrimp the germ is seen developing below the yolk.

[PLATE III—YOUNG SHRIMPS.]



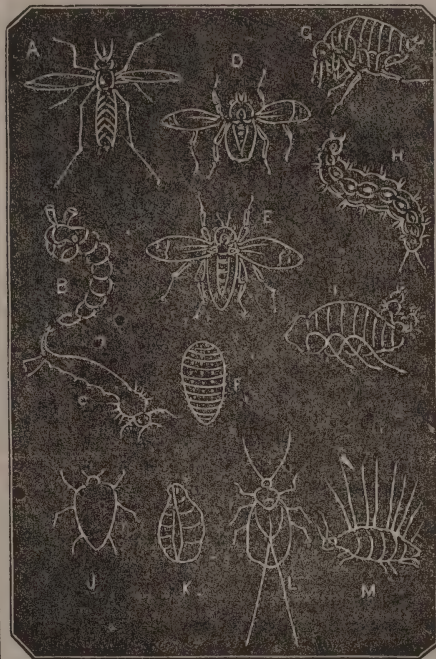
The details of these metamorphoses I shall illustrate thereafter. I mention it now, only in order to add, that this mode of growth is not peculiar to insects alone, but that it is characteristic of most Articulata to have this inverted mode of growth from their earliest embryonic condition.—They grow, as it were, in opposition to all other animals. And it is a fact in no small degree remarkable, that among such animals there should be such a number of Parasites. Articulata are, however, the only type in the animal kingdom in which parasitism is the prevailing rule, though there are other Parasites which belong to other classes.

The metamorphoses of Insects which take place after the little Larva (as Entomologists call the earlier condition of the animal) is born, have been extensively studied. This little Worm (Plate VII, fig. F) is like the primitive form of the common Mosquito, of which we see (Plate IX, figs. B, B, C) all the different changes which the animal undergoes before it is changed into its perfect state. Figs. D, E, F represent the same successive changes from the Horsefly (*Cestrus*); figs. G, H, I, those of the common Flea; figs. J, K, L, M, those of the Cochineal. In plate X, the figs. A, B, C represent the egg, larva and perfect Hemerobius; figs. D, E, F the metamorphoses of a Moth, of the genus *Geometra*; figs. G, H, I those of *Phryganea*, and figs. J, K, L those of an *Ephemera*; plate XI represents Beetles; figs. A, B, C the metamorphoses of a *Dermestes*, whose larva is hairy and colored, like that of a Butterfly; and figs. D, E, F, that of a *Cetonia*, in which the larva is a Maggot.

The Naturalists of the last century have studied,

more carefully and more extensively the metamorphoses of insects than the Entomologists of the present day. It is to works long since almost forgotten among entomologists, that we must resort to find extensive, minute, and correct information upon the metamorphoses of Insects in their various stages of growth. Swammerdam, in his Bible of Nature, full of interesting details, has given a great variety of metamorphoses. So have the investigations by Degeer, Geoffroy, and Rosel, done more in this department than all modern investigations put together.

[PLATE IX—METAMORPHOSES OF THE MOSQUITO, HORSEFLY, FLEA AND COCHINEAL.]



The title of Rosel's work, which he styles "*Amusements with Insects*," (*Insekten Belustigungen*) shows how much he must have enjoyed his researches. He has, perhaps, illustrated the metamorphoses of insects more fully than they have been examined before or since. In our modern times, Entomologists have devoted almost all their attention to the study of genera and species, of the external forms of families and specific distinctions, and have in this way, endowed Entomology with treasures of detail, but have made very few references to the study of metamorphoses, which would however, render this minute knowledge of details much more valuable; for if the changes which take place in various families were brought under rules, these details would at once be made useful in the comparison of extensive series. But, for the present, we have only to hope for a general comparison between the modifications of parts as they occur

in the larva state, with those of perfect insects. I would, however, except from this criticism some few modern authors, who have followed the glorious tracks of the great Entomologists of the past century. Eminent among such exceptional works containing more than descriptive details, stands the remarkable report of Dr. Harris upon the Insects of Massachusetts injurious to Vegetation, in which the author has given most valuable information upon the metamorphoses of insects living in this State. Also, Professor Audouin has given many beautifully illustrated facts about the insects injurious to grape vines. Ratzenburg has made similar investigations on insects injurious to the forest trees in Germany. To these works we shall have constantly to refer when studying the metamorphoses of articulated animals.

The larvæ differ from each other, not only in form but also in structure, and in the successive changes which they undergo. There are larvæ which arise from the egg almost under the same form as the perfect insect, and in their metamorphoses undergo only slight changes of form; perhaps changing the length of their legs, or modifying the apparent number of rings which they had when coming out of the egg. There are others which are born widely different from the perfect insect, which will remain in that form for a certain time, and then change into an Animal entirely different in its outline—to remain in that condition again for a longer or a shorter period, and then to undergo the last transformation. Insects which undergo such complete changes in form, are called insects with perfect metamorphoses. Those into which changes are introduced gradually, and in which the differences in various periods of life are not so great, are called insects with imperfect metamorphoses, or half metamorphoses. We have insects in which the young are born under nearly the same form as the perfect insect. I would mention the Grasshoppers, for instance, in which the young have the same forms except the wings, which are wanting. The greatest differences are noticed among Butterflies (Plate II, fig. C), where

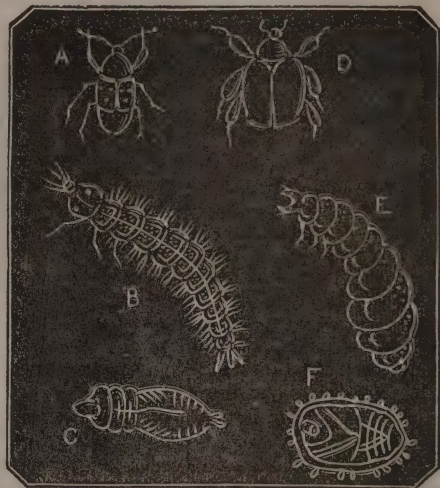
[PLATE II—CATERPILLAR PUPA & BUTTERFLY.]



the Caterpillar is first seen (Fig. A), next the Pupa (Fig. B), and lastly the perfect animal (Fig. C); also in the Beetles (Plate XI, Fig. D), where the form

represented by figure E, is first seen; next the Pupa (Fig. F), and then the perfect condition (fig. D). Fig. A. represents another Beetle in which the larva (Fig. B) is similar to the Caterpillars. In most insects, the larvæ, when colorless, are called Maggots, or Worms. In the Ephemera (Plate X, fig. L), we have the same form of the body as is seen in the perfect insect; but on the sides of the larva there are aquatic respiratory organs, gills, (Fig. L.) which do no longer exist in the perfect insect (Fig. J). Such cases indicate the extensive differences of structure which may exist among larvæ of the same class.

[PLATE XI—BEETLES WITH THEIR LARVÆ AND PUPÆ.]



Some (Plate X) have aquatic breathing organs, and others aerial ones—a difference which in other departments of the animal kingdom is considered sufficient to divide some of them into different classes. Fishes and Reptiles are not left in the same classes, because the respiration of the one takes place by gills, and in the others, by lungs.—You will notice in this figure, (Plate X, fig. L) and in Plate XI, fig. A, considerable differences: in the one there are gills, and in the other lung-like organs for the same function.

In others we see still different combinations. In the Phryganea, for instance, (Plate X, fig. H) there are legs only upon the anterior rings, and there are stiff hairs upon the other rings; whilst in the Caterpillar (Plate II, fig. A) there are legs upon the anterior part of the body; others on the middle joints; and still others, behind. The larva of the Horse-fly (Plate IX, fig. F) has no legs at all, only stiff hairs. In the Mosquito (Plate IX, fig. C) the larva is aquatic, provided with gills. The pupa (Fig. B) assumes another form, but remains aquatic, and finally, the animal appears with legs in a very different form (Fig. A) and with a pair of long wings and various appendages in addition.

Now, it is important—I insist upon this point—not only to trace the changes which the larvæ un-

dergo in their metamorphoses, but also to investigate the changes in their structure, which are brought about during their metamorphoses; and happily we have upon these points most admirable investigations by Dr. Herold, though upon only one species, the white Butterfly which feeds upon the cabbage. It is remarkable, however, how few investigations have been made upon these animals at large, when we take all points of view into consideration; and we find ourselves reduced, for illustration to one single well studied example. Prof. Herold in his admirable work begins, unfortunately the investigation only with the full grown Caterpillar, which he goes on comparing with the pupa, and then with the perfect insect.

Now with reference to these differences between the larvæ—before I allude to peculiar differences of structure—let me make another general remark. There are groups of insects in which considerable differences occur among the larvæ, even in their structure, when the perfect insects constitute natural families, and are identical in structure. Again, there are others, the Butterflies for instance, in which the larvæ agree as perfectly as the full grown insects, having all a distinct head (Plate II, fig. A), with powerful jaws, and a slight indication of eyes. Then, we find upon the three anterior rings there are three pairs of legs provided with horny claws, next two rings without legs at all, then, rings with feet of an entire different structure, resembling suckers, then two rings without legs, and a pair of legs upon the last ring. And this arrangement of parts is uniform through all Butterflies. It occurs in the Diurnal as well as in the Sphinx and Nocturnal Moth. The larva of Butterfly is never an aquatic animal, but is always an air-breathing creature, but there are many aerial insects whose larvæ are entirely aquatic.

Another difference is, that these insects in their lower condition have powerful jaws, by which they chew their food, moving their jaws from right to left and from left to right, on the two sides; while the perfect animal is very different in having no longer jaws to chew the food, but suckers to take food from the nectar of flowers. And the change in the mode of living is so great, that the Caterpillar will consume ten times his own weight of food in a given time, while the perfect animal will not consume more than one tenth of his weight during all the remainder of his life, as a perfect insect.

This fact has great importance in connection with one question about which Naturalists have had much discussion, viz: whether the insects which chew their food should be considered as higher than those which suck their food by suckers. The Insects provided with powerful jaws—the Beetles, the Wasps, the Humbees, Dragonflies—all these insects, which have powerful jaws, are generally considered higher in their structure, because so many of them are carnivorous, and stand in our systems as at the head of insects; whilst the sucking insects are placed in a lower

range. That the former are placed higher, arises from no other reason, I think, than the fact that there are so many of them which live upon animal food, or which are properly carnivorous: and as we are accustomed from our intimate acquaintance with mammifera to consider Carnivora higher than Herbivora, we are naturally misled to consider all carnivorous animals, for the simple reason, that they are carnivorous, as higher than the herbivorous ones. But such impressions can have no value in the estimation of the characters of animals of another department. The larvæ of many sucking insects have equally powerful jaws as the carnivorous, which are made into another apparatus of an entirely different structure, introduced in the last transformation of the insect.

[PLATE V—ARTICULATA—TRILOBITE.]



My impression is, therefore, that on this account we should rather incline for an inverse view of the subject, and an inverse arrangement of the insects, and consider the sucking insects as higher than the chewing Insects. And I would place the Butterflies highest, for the reason that they undergo such extensive metamorphoses—passing through so many changes in which the structure grows successively more perfect. That they should be placed highest amongst the sucking insects will be obvious, when we consider that they are aerial worms from the beginning—while other insects, with the sucking apparatus, as Flies and Mosquitoes, constitute a family in which there are many aquatic worms, and we know from other departments, that aquatic animals provided with gill-like apparatus are universally lower in structure than those which breathe air. But such a uniformity in larvæ as we have among Caterpillars is not noticed in other insects. You can of course compare the larva of Dermestes (Plate XI, fig. B) with a Caterpillar, (Plate II, fig. A.) But, of the external appearances, the appendages of the skin agree; the arrangement of the feet will be found different.

The aquatic insects have their larvæ still more different, being provided with gills, so that the external form in its earlier condition, is far from uniform in the families which reckon aquatic types. Among the hymenopterous insects, Bees, Wasps, &c., we have some in which the larvæ assume the form of Maggots and Worms, and others in which the larvæ assume the form of the higher insects. For instance, in Tenthredo, the larva assumes the form of a Caterpillar. (Plate II, fig. A) But instead of having only four pairs of suckorial feet, they have seven. And this is at once an indica-

tion that they do not belong to the family of Lepidoptera.

I see the time will not allow me to go through the whole of this extensive subject; so that I shall call your attention again in my next lecture to the transformation of structure which takes place in these animals. Let me only make one remark more with reference to the relative position of the various families of the numerous order of insects, and to the relative value of their distinguishing character. Why should we be led to arrange the insects and articulated animals in a natural order, by other considerations than those derived from their own mode of growth? For, if we find that in insects the earliest period of life is that of the carnivorous animals, let that be the lower condition for articulated animals. And if we see that they successively undergo changes, in which, growing to our eyes to more perfect animals, they finally

assume the structure of sucking insects, then let us consider the condition of sucking insects the higher condition. And let us no longer transfer our impressions from one department into the other. The same difficulties occur really in all other classes. Because the Carnivora among Mammalia, come so near to the Monkey, and thus approach to the affinity which raises the Monkey next in rank to man, it is no legitimate consequence, that the Birds of Prey should be the highest. Nor does it prove that the carnivorous fishes should rank higher than the others; and still less, does it follow, that the chewing insect should take the highest rank, especially when we see that the chewing condition is the lowest embryonic condition of their life. And let us, in future, arrange insects according to the rule of insects, and not according to the structure of other animals.

LECTURE VII.

Before entering upon the proper subject of this evening's lecture, I have to mention a few facts which I have ascertained upon the growth of some Polypi (or rather Medusæ, if Tubulariæ have to be considered as Medusæ) which I consider so highly valuable as to deserve really to call our attention for a few moments. I have received from Mr. Hawks, of the Navy Yard in Charlestown, a bunch of Polypi, taken from the bottom of a ship which has been lying for three months and a half in the harbor. When she was launched, on the 14th of September last, she had, of course, none upon her. She had been lying in the water from the 14th of September to the 28th of December, when she was taken into the dry dock. During this time, the bottom of this ship has been covered with the most astonishing, the most luxuriant growth of Polypi which can be imagined. Thousands and thousands of Polypi stems, as long as five, or six, or seven inches, forming the most beautiful flower garden, upon the bottom of the vessel. And not only have all these Polypi grown to this size, but they have branches, and these branches—these secondary branches—have given rise to branches of a third order, in this short time. Now, the question is, how can these innumerable stems have grown upon this vessel? They could not have been attached to it accidentally, as Tubulariæ, in their ordinary growth, are always attached, and when freed, fall to the bottom, without having the means to move

about. The uniformity of their growth, shows that they have grown upon the vessel from a uniform starting point, not from a certain number of stems which had accidentally become attached to the vessel; all of which must be supposed in the same condition, in the same state of growth, when they became attached, and that they have grown upon this vessel naturally, uniformly, up to the present day, or rather up to last week. But to be attached there, in such a manner, not accidentally, they must have been free; and it is just a point to which I alluded in a former lecture, whether Tubulariæ had or not, a free generation, alternating with their fixed growth. A free generation among them is not known; yet I inferred from some data, that the affinity of Tubulariæ with Medusæ was very close, and I ventured even to predict that some one of the small free Medusæ of Boston harbor might be their free form—that a free generation might be found.

Now, the circumstances above stated, show that there must be a free generation of Tubulariæ, which, by the 14th of September, or some time later, were swimming in Boston harbor in countless numbers, and attached themselves to the keel of that vessel, and grew there to form these innumerable stems. Whether this growth is immediately derived from the germs, which are produced in the bunches, which are known to exist in Tubulariæ, or whether it is only another generation, derived

from that free one, is still a point which only direct investigation can ascertain. I incline to suppose, that the Medusa-like germs which are developed from the bunches of eggs, hanging below the outer tentacles, are the intermediate, free generation which grows to lay moveable eggs, similar to those of Campanularia; and that these eggs, and not the soft free buds, grow into Tubulariæ. However, so much, at least, can already be inferred with precision: that Tubulariæ must have some free generation,—a generation which is about to attach itself in the latter part of September, and to produce a luxuriant growth of common branching Tubulariæ.

Now, how rapid this growth must have been, and how rapidly the branches must have succeeded, an illustration of the details will show. Each single, isolated stem, from five to seven inches long, terminates with a crown, having its tentacles and bunches of eggs, like the most perfect Tubularia I have seen. The terminating Polyp has bunches of eggs, and all these eggs have already their yolk, with its envelope—their germinative vesicle, with its germinative dot. The lateral branches, perhaps five or six, in various stems, growing from different parts of the stem (but the lower always, in every case, being longer than the upper ones,) were terminated also with regular crowns; but those smaller and simpler individuals, the number of their tentacles being fewer, were found to be without any eggs. They had not grown to the formation, to the development of organs of reproduction. The tertiary branches, sometimes as many as five or six upon one of the secondary, were found to terminate also with a small Polyp; but like the secondary, to be without eggs. Hundreds of these branches, compared together, showed no difference. They were so alike as to indicate, distinctly, that they were the growth of one epoch;—that they had been attached to the vessel at one time, and had grown under identical circumstances. That stems already formed, could not be attached to the vessel, is shown by the circumstance that the loose branches sink to the bottom, and have no means of transportation from one place to another. Thus, the being which was fixed, must have been a free animal. You remember, perhaps, what I have said in a former lecture upon the embryonic growth of Tubulariæ. I showed the formation in the bunches of eggs of little Medusa-like beings, with four or more arms,—four prominent ones, and others alternating with them, less developed, which became free, but whose final development had not been observed. I now suspect that these Medusa-like buds would grow into Medusa-like animals, and that these Medusa-like animals would lay eggs, and that these eggs, like those of Campanulariæ, being first free, would then become attached—grow to a disk-like surface, rise from the centre to a stem-like growth, and then pass through the same metamorphoses which have been observed in the Cam-

panulariæ. At all events, here is one fact in the history of this animal ascertained, which was unknown before—the fact of its rapid growth, of its rapid branching, and of the existence of a free generation, though not ascertained by investigation, so strongly indicated by circumstantial evidence as to be almost a positive fact, in the opinion of one who has been accustomed to compare these phenomena and to refer them to a common type.

In my last lecture, the first upon articulated animals, I began by illustrating, in a general manner, the character of the great and numerous type of Articulata; how they are subdivided into three classes—the Worms, Insects and Crustacea—or in the order which I would prefer, Worms, Crustacea and Insects; then further, I alluded to the peculiar characteristics of insects, to their extensive metamorphoses; and then more fully illustrated the embryonic growth of these animals, as ascertained by the investigations of Professor Kolliker; and finally investigated the different metamorphoses in different families of Insects.

We now proceed to the investigation of the changes of *structure* which these insects undergo during their metamorphoses. We have examined the general changes of *form* which these animals undergo in various families. We have now to examine the changes in the internal structure, which take place in the larvæ of Insects, till they acquire their perfect development. And in tracing these changes, we shall acquire an invaluable key to appreciate the relative value of the differences which exist between all insects—between articulated animals at large.

If it is true that Insects are the highest among articulated animals, even if they should occupy a second rank, a thorough acquaintance with all the changes of structure which they undergo during growth, must give us a key to appreciate the real value of these differences, their relative order of succession in a scale—in a gradation of structural differences.

The value of these comparisons must be so obvious, that I need not apologize for dwelling more extensively upon these topics than I would otherwise. I repeat it—that the facts which we are now about to examine will furnish (if there is one) the key for estimating the value of characters in one of the greatest types of the animal kingdom.

In Plate XII are diagrams representing the nervous system of a White Butterfly, (which is exceedingly common in Europe) living upon cabbage, in its various stages of growth, as figured by Herold, in his remarkable work upon the metamorphoses of that animal. In Plate XIII are diagrams representing the changes which take place in the digestive apparatus of the same animal; and here (in Plate XIV, figs. A and B) are represented longitudinal sections of a Moth (Fig. A) and its Caterpillar form (Fig. B) from Prof. Newport's researches, to show the different systems of organs in their

relative position within, and also the changes which they undergo during their growth, as well as in their proportional development. To these diagrams I shall mostly refer during this illustration. But in such a comparison of structural differences, the external arrangement of parts is as important as the internal differences.

We have examined the *forms* of the various stages of growth in Insects. We have not examined the differences in the arrangement of the external parts. Let us begin the comparison with these.

[See Plate IX, Lecture 6.]

In the various Caterpillars or Maggots—in the various larvæ of Insects which you see figured in Plates IX, X and XI, and Plate II of the first lecture, there is one form which is characteristic in all—which occurs universally in all. It is the greater uniformity of rings when compared to each other. The rings of the anterior part of the body, (Plate X, fig. H, or Plate XI, fig. B)

[See Plate X, Lecture 6.]

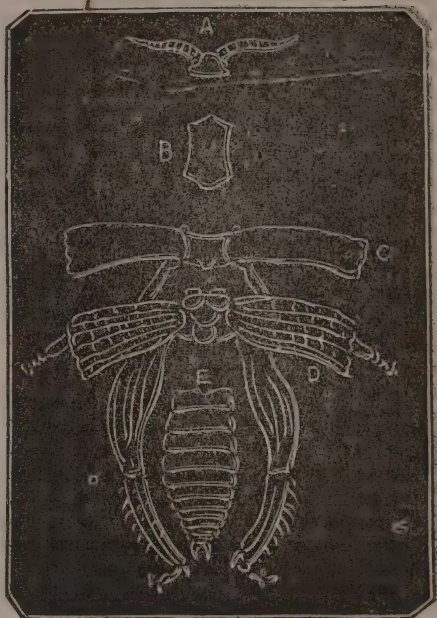
though here provided with legs, resemble the rings in the middle portion of the body; however, they resemble these more closely than the anterior rings resemble the posterior ones; but as a whole, considered in its general arrangement, the various rings of the larvæ are more uniform than in the perfect insect, which arises from them; and they are naturally more uniform, but they are not grouped together in any particular way. There are no differences in the rings, indicating more circumscribed parts of the body. Scarcely is the head more defined from the other rings by its color. But, between the so-called chest of Insects and the abdominal region, there is no separation (see Plates IX, X and XI) as we notice it in the perfect insect.

There is always in the perfect insect, between the head and the chest, and the posterior part of the body, a strong division, as we see in these figures, (Plate XI, figs. D and A) where the head is more distinct; a certain number of rings constitute another region behind the head, the so-called *thorax*, or chest; and behind this, there is a third one—the abdomen. Now, such a division of rings into distinct divisions—into a head, thorax and abdomen—is not yet introduced into the condition of the larva, though it is indicated by the appendages; though not universally, but very generally, there are among the anterior rings some which have appendages more developed than the others, which will correspond with the rings which form the chest, and, then the other rings behind will correspond with the rings which form or constitute the abdomen.

But now, compare the proportional size between those rings in a perfect insect—Grasshopper for instance as in Plate XV.

Here (Fig. A) is the head. This middle region, here separated into its constituent rings, (Figs. B, C, D) will correspond with the chest; and here,

[PLATE XV—GRASSHOPPER.]



posteriorly, a portion of the body, scarcely larger than the head and thorax together, though composed of twice as many rings, corresponding to the abdomen. In the imperfect larva (Plate XI, fig. E) we have precisely the reversed proportions in the size of the rings of the different regions of the body, or what will finally constitute these different regions. The posterior rings in this case are reduced considerably in the perfect condition, but the rings giving rise to the thorax are enlarged, and closely united in fewer joints, so that there is a real reduction of rings, and a real reduction of the moveable parts, inasmuch as the three rings of the chest, which in the earlier stages are equally moveable upon each other, now are united together, and form only one mass. The reduction, therefore, of the number of rings or their closer combination, or the reduction in size of the posterior ones, with a proportional increase of the anterior ones, when they acquire a higher development, are stages of growth which indicate a progress—a really progressive development.

From these first superficial investigations, we learn one important fact in Entomology—that elongated species, in any given type, consisting of well divided, uniformly moveable rings, must be considered as lower than those in which the rings combine or unite together, and divide into distinct regions. So that the Caterpillars give us the first hint towards a classification, namely, that Insects, or Articulata at large, stand higher or lower, inasmuch as the rings are more or less numerous or reduced, uniformly moveable or combined, unconnected, or united into distinct regions.

[See Plate IV, Lecture 6.]

And if we test with this first result the proposed modifications in the general classification of Articulata, we will find that on this ground Worms (Plate IV) will stand lowest, Crustacea (Plate VI) come next, and Insects highest.

[See Plate VI, Lecture 6]

Let us now examine the changes which take place in the nervous system of the Caterpillar when full grown, (the changes during the growth of the Caterpillar itself have not yet been investigated) till it is transformed into a perfect Butterfly. We have at first, a nervous system, consisting of a series of equally developed and almost equally distinct swellings (Plate XII, fig. A)—in the head two large ones; next, one small one; at about an equal distance, a second; a third, nearly equally distant; a fourth, somewhat more distant; a fifth, sixth, seventh, eighth, ninth, tenth, eleventh, almost uniformly equally distant; and then a twelfth, which is nearer the eleventh, making, with the head, thirteen. Now, precisely the same number of nervous swellings which we observe, constitute the number of rings existing in the Caterpillar.

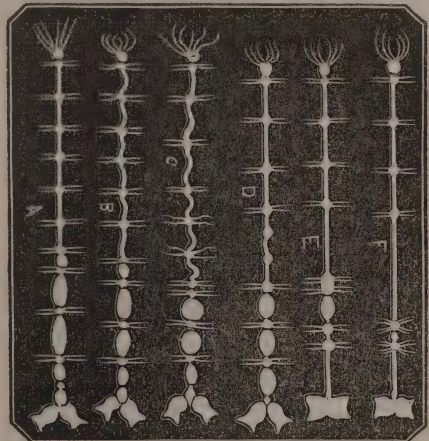
Uniformly, throughout the family of Lepidoptera, that is to say, among Butterflies and Moths, the body consists of thirteen successive rings; and in the lowest condition of these animals—in their caterpillar state—the nervous system has as many nervous swellings,—one for each ring, almost equally distant from each other, and sending off threads to the parts around in each ring. The general structure and position of the nervous system is as follows:—The swellings are throughout united by double threads, which towards the posterior part of the body come so near together as to seem a continuous, thick cord; but properly speaking, they consist uniformly of double threads. And in the position of these threads, there are some important points. The anterior ones are above the alimentary canal; the others are below; so that the thread which unites the anterior ones with the second, constitute a sort of collar around the alimentary tube (Pl. XIV). But all the swellings are united by double threads, even where the threads come near together and seem to be one continuous cord. I insist upon this point, because it shows the uniformity of structure of the nervous system in all articulated animals, and illustrates it, even in the structure of the nervous system which has recently been discovered in Intestinal Worms. When discovered, it was supposed that Intestinal Worms had a nervous system so different from Articulata as not to belong to that group. The nervous system in Worms forms a sort of collar, with swellings around the anterior part of the alimentary canal, from which arise a double row of swellings, connected by simple threads, extending backwards.—This arrangement is indeed not very different from that of the higher Articulata: let only swellings, with their double threads, be disconnected, and we have the arrangement of Worms; and let the

two chains of Worms be united in one, and we have the arrangement of Insects.

As soon as the Caterpillar undergoes the first change towards forming the Pupa—towards becoming immoveable, before it casts its skin for the last time—we see (Plate XII, fig. B) that the third and fourth swellings are brought nearer together; and also the first and second are brought nearer together; the others remaining in the same relative position and in the same proportional distances apart.

But as soon as, for the last time, the Caterpillar has lost its skin and assumed that peculiar form of Pupa in which it is motionless, then the nervous system in its longitudinal extension assumes this winding form [Plate XII, fig. C.] It brings the swellings nearer together, the first of them being at this time entirely united with those at the head.

[PLATE XII—NERVES OF BUTTERFLIES]



In the following stage, (Fig. D) the 2d, 3d, 4th and 5th swellings are brought nearer the head, whilst the 6th, and 7th, disappear entirely during the pupa state, and with them disappear also the lateral threads which arose from them in an earlier condition. The second, third, fourth and fifth swellings remain now for some time at the same distance, but are gradually combined in one single and more connected mass. The sixth and seventh, disappear. The eighth, ninth, tenth and eleventh remain at equal distances. And if we compare this condition with the perfect insect, we can see that these few anterior swellings, though arising from five distinct ganglia, will send the nerves to the parts answering to the chest. A region behind, with the long medial thread without lateral nerves, is the region where the separation between the chest and abdomen will take place. Before the Pupa passes into the state of the perfect insect, the approach of the swellings number two, three, four and five is still increased. So that there are now only three regions of distribution of the nervous centres: the head with one large mass; next, the chest with septated, though approximated

swellings; next, a great space without lateral nerves; and then, a space with swellings at equal distances, corresponding to the abdomen. Remember now the arrangement of rings and legs in the Caterpillar and in the Grasshopper, [Plate XV]. You will see that the arrangement of the external parts agrees with that of the nervous system. The head consists of one undivided mass [Plate XV. fig. A] There are three pairs of horny claws in the Caterpillars (Plates IX, X, and XI,) and three rings to the chest in the Insects proper, (Plate XV, figs. B, C, D) receiving nerves from the concentrated swellings of the anterior part of the body. Then, there is a region from which no nerves are derived; and a region from which four pair of sucker-like legs are produced, answering to the region in which these four swellings remain equally distant; and then another region, of two rings without; and another, last, with suctorial legs, which corresponds to the large terminal nervous swelling.

It is a question which it is not possible to solve now, and which it will be very difficult to solve, if it can be solved at all, whether the larger terminal swelling of nervous matter consisted originally of one nervous mass; and whether the anterior cephalic ganglion consisted also, primitively, of one nervous mass. That it consists of two now, is shown here, [Plate XI. fig. A] by the entire disappearance of the first small ganglion. But there may be other changes in the structure of the nervous system, taking place previous to the full growth of the Caterpillar. And this remains for the present undecided. But, so much is shown as to prove that the nervous system is equally distributed in the solid rings, and they will gradually combine in such a manner as to present arrangements answering to the changes which take place in the external form. There is one mass more, properly belonging to the head, another mass more concentrated, belonging to the chest, and another mass remaining stationary and belonging to the abdomen.

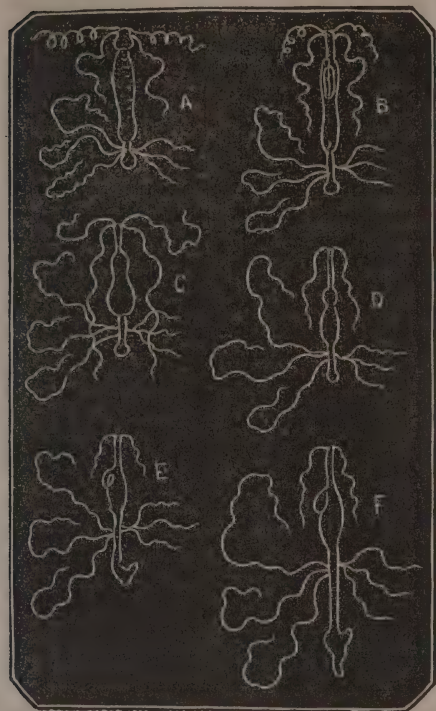
We now can, with these facts, arrive at another general conclusion, viz.: that wherever among articulated animals, among Insects, we find the nervous system constituted of equally distributed nervous swellings, such animals are lower than those in which several swellings unite together to form few masses. Now, in this respect, what do we observe in the different classes compared together? I now no longer compare the same animal in its different stages of growth, but different classes of Articulate with each other. What do we observe in comparing Insects with Worms, and Worms with Crustacea? All worms have equal rings and very numerous joints; and joints which are never combined so as to form regions distinct from each other. There is never a distinct thorax or abdomen in any Worm. So that, from what we have learned, we know that the lower position assigned, for many and all sorts of good reasons, to worms, is the proper position which they must preserve;

and where a nervous system has been observed among them, it agrees with the condition of that system in Caterpillars, rather than with that of the later metamorphoses. The question remains between Crustacea and Insects. What is the condition of the nervous system in Crustacea? The nervous system occurs in various conditions there. In the lower Crustacea, the swellings being scattered all along the body, one to each ring—a condition which we observe in the earlier stages of growth in the Caterpillar. Next, we have other Crustacea in which the nervous swellings contract and combine together, nearer and nearer. But in them, strange to say, there is only one point of concentration. And then there are Crustacea, as the Crabs, in which the nervous system is contracted into one single, central mass. And the question is, what shall we consider superior?—an arrangement which gives rise to several distinct centres, and corresponds to distinct regions of the body, (as in Insects, Plate XII., fig. F, and Plate XIV, fig. A) a head, with a central nervous swelling of a peculiar kind; a chest, with a nervous mass of a peculiar kind, sending its thread to the legs of that region; and another posterior combination of nervous swellings, corresponding to the other region, called abdomen, and sending nerves to its part?

It seems to me that we cannot remain doubtful. We cannot fully derive this conclusion from direct investigations, as we have not, in any instance, a case to settle it by direct comparison; but we may say, that in Crustacea we have concentrated uniformity; while in Insects in their perfect condition, we have concentrated diversity. And, if we are allowed to compare the one with the other, I would incline to the opinion that concentrated diversity, with prevailing influences over peculiar functions of the life of the different centres, is a condition of structure which stands higher than concentrated uniformity, in which we have only one centre. We have all the primitive diversity reduced to one centre, which does not acquire any distinct influence upon different parts.

The alimentary canal undergoes corresponding metamorphoses. Here is the straight tube (Plate XIII, fig. A) of the digestive canal of a Caterpillar. It is very wide in comparison to its length, and capable of digesting an immense mass of food, comparatively to the size of the animal. In its earlier condition, it is provided with an apparatus which disappears afterward. There are considerable salivary glands in the anterior portion of the alimentary canal, which disappear in the pupa state and do not exist in the perfect insect. These figures (Plate XIII) must impress you as very singular.—No animal has more curious organs than this insect. The liver, or hepatic glands, and the salivary glands are massive organs in other animals. Here, they are slender tubes, and form little winding branches on the sides of the alimentary tube. Indeed, all glandular organs in Insects have such a

[PLATE XIII.—ALIMENTARY CANAL OF BUTTERFLIES]



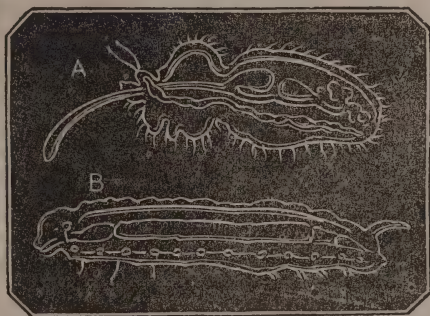
general arrangement—they are all tubular, thread-like, and very long.

The next glandular apparatus here (Plate XIII, fig. A.,) is the gland seen on each side, behind the salivary tubes, the silk glands, which are much larger in the Caterpillar than in the perfect insect. These silk glands still exist in the perfect insect, but they are much larger in the Caterpillar than in the Pupa, and again larger in the Pupa than in the perfect insect. You are aware that the Caterpillar draws its silk from its mouth, winds it regularly around its body, to protect it during its second stage of metamorphosis. The third glandular apparatus, a kind of liver, consisting of three pairs of hepatic tubes, emptying in the posterior part of the wide tube of the Caterpillar, but about its middle in the perfect insect. This condition of the glands, which we find among all the Insects, is far from the structure of those massive glandular organs which occur in other animals. The lower portion of the alimentary canal is scarcely at all contracted, in the Caterpillar, as you will observe in this figure (Plate XIII, fig. A.) Before entering the pupa state (Plate XIII, fig. B.,) at a period when the insect is more perfect, the oesophagus has become narrower and longer; and the colon has also become more elongated and narrower, and in the pupa state you see how the digestive tubes appear.

(Plate XIII, figure C.) The animal has now ceased to take food, and the salivary glands disappear entirely. (Plate XIII, fig. D.) Next, the colon grows more slender, to be transformed into a narrow cylindric tube. When the Pupa is ready to be transformed (Plate XIII, fig. E.,) into a Butterfly, there is a new pouch formed between the oesophagus and stomach, a pouch which secretes the honey. It is a sack, to produce the sweet fluids which so many insects are capable of secreting, or at least of preparing. This pouch (Plate XIII, fig. E.,) has grown to a somewhat large size, and the posterior part of the alimentary canal has been elongated very considerably, in proportion as the middle part or the stomach proper has been reduced. And finally, in the Butterfly, it is fully developed, but we see no longer any salivary glands. (Plate XIII, fig. F.) The posterior part of the alimentary canal is now long and slender, and the hepatic duct of the liver nearly as large and as complicated as in the beginning.

Here again, we see that in proportion as the alimentary tube is a uniform tube—or in proportion as there are cavities of different diameters developing along its longitudinal diameter—we have another scale to determine the relative rank of animals in which this organization is observed.—

[PLATE XIV.—LONGITUDINAL SECTION OF SPHINX LIGUSTRI.]



This is, perhaps, better seen in another diagram of a Moth, where we see the oesophagus passing through the anterior nervous ring, and extending in the perfect insect Pl. XIV. (Fig. A) through the chest, where the wings are cut off and the legs also. The large thorax answers to that part of the Caterpillar (Figure B,) where the horny legs are seen, and the ganglionic portion of the nervous system is seen all along below the alimentary canal. And in the Caterpillar you see how intimately and uniformly the nervous swellings follow each other, (Plate XIV, fig. B) and how the alimentary canal is a uniform tube, whilst in the perfect insect, alimentary canal and nervous system have undergone remarkable concentrations (Fig. A).

Another apparatus is very simple among Insects. It is one of those functions which is not so highly developed as in other Articulata, but which,

nevertheless, exists. There is a circulation in Insects which is only more generally overlooked.—The heart is a more elongated tube than in Crustacea, but it exists in all insects. It exists more developed in their larval condition, which shows that having a large heart in articulated animals, is not characteristic of a higher structure; and how a great bulk of blood can be concentrated upon one point in Articulata, without assigning them a character of great eminence, is distinctly shown, when we consider that in Worms, which undoubtedly stand below the other two classes, there are as many as six, eight or more hearts, and in which the bulk of the blood is proportionally much greater than in Crustacea or in Insects; so that, the importance ascribed to the circulation of Crustacea, when this class was placed above Insects, I think vanishes before the consideration of the value of these characteristics, as noticed throughout the metamorphoses of Insects.

A few words upon the subject of mastication and upon the chewing orders, will further show that Insects have to stand higher than other articulated animals. The chewing apparatus in Insects is a very complicated apparatus, so complicated that it is scarcely possible to give a correct idea of the arrangement of these parts, unless a person has become familiar with the objects themselves.

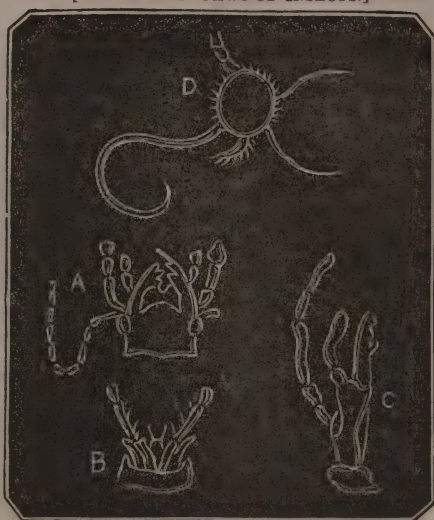
I must, however, attempt to convey some idea of this apparatus. On the two sides of the head in those insects which are generally considered the highest, there are two large moveable pieces, moving from right to left on the right side, and from left to right on the left side, in opposite directions horizontally. These parts are called mandibles.—Below these, is another pair of similar organs, moving also horizontally, which are often serrated, and to which are frequently added articulated appendages; these are called the maxillæ.—These constitute two pairs of strong forcep-like jaws, very different, it seems, from any part in the whole insect.

In the diagram here, Jaws of Insects (Plate XVI. figs. A, B) you see the whole apparatus, first from a Beetle and a Grasshopper, (fig. C). Seen from above (fig. A) there is a kind of lip in sight, covering the mandibles, and below, are the maxillæ; and below (fig. B) there is another kind of lip, keeping these in their respective positions. To the lower lip are also frequently appended articulated tentacles—the palpi. Fig. C. represents the maxillæ of a Grasshopper seen in profile.

Now, each of these parts being taken asunder, we will have a strong mandible above; and somewhat below and inward, the maxillæ; and farther below, we have the lower lip. So that, between two horizontal continuous plates, called lips, there are moving forceps, the upper, called mandibles, and the lower maxillæ. Then we have maxillary palpi. And to the lower lip there is another pair of palpi attached—the labial palpi.

This is the structure of the jaws in all chewing

[PLATE XVI—JAWS OF INSECTS.]



insects. The Caterpillars have also such maxillæ as the perfect chewing insects, though not so complicated, to be sure, as in the most perfect Beetles, but nevertheless constructed in the same way, with a horny, powerful jaw, by which they chew the large quantity of food which they devour. Now this condition is changed in the Caterpillar during the pupa condition, when we have no longer such enlarged jaws; but a long sucker, [Plate XVI fig. D] consisting, however, of the same parts as in the chewing insects, only those parts which were moving horizontally have become elongated, and with their margin have united, and instead of now moving in that way, remain closed together, and form, a tube, a real sucker, through which, by the assistance of the tongue, they actually pump liquid food into their stomachs. (The Professor here represented, by means of his fingers, the jaws of the chewing insect, and the manner in which, by uniting, they can be transformed into a sucker.)

Let the tube now be contractile and retractile, between the upper and lower lip, and you have powerful jaws transformed into a narrow tube. It is a transformation which takes place with the other successive and progressive changes, so that we are entitled to consider such changes as also a progress, if I am not mistaken; and to consider the condition of the insect in which he chews food, as the lower one, as it is the condition of the Larva; and the condition in which he sucks, to be the higher condition of the insect. And therefore, in principles derived from the study of Insects, and not from the study of other animals, judging of Insects by notions gained from that class, we shall consider those which suck their food, in which the jaws are elongated, those which pass through various metamorphoses, higher than those in which the jaws are placed horizontally—sharp cutting jaws, which devour large quantities of food. But this

condition of jaws, I say, is of higher structure than that which is observed in Crustacea; and affords an additional evidence than Insects should stand above Crustacea. To show this to be the case, let me first answer a question. What are these jaws in Insects? By most difficult and extensive comparison, it has been ascertained that the jaws are simply modified legs, and that there are all possible transitions to be observed in the various families, between their ordinary legs and that peculiar kind of moving appendages which perform, the function of jaws, but which are so exceedingly different, owing to the great eminence in form to which they arrive.

Now in Crustacea, the changes which take place between the appendages functioning as legs, and those functioning as jaws, are so slight as scarcely to present any difficulty in ascertaining their common nature; the differences are much less plain in Insects, with their different sorts of jaws. You scarcely can find the combining thread, showing that in Insects there is one, and an uniform modification of appendages in legs and jaws. But compare, on the other hand, various appendages of the Crustacea, and it strikes us at once that they are the same thing, slightly modified.

Before I illustrate this point, let me remark, that on looking at this diagram, there is scarcely any one who would suspect that these figures represent any thing more than the various claws which are observed on the side of the lobster. And so it is; but nevertheless, some are jaws, others claws, others fins; the jaws being somewhat modified legs; so that those parts are only a little diversified among each other. We have something left of uniformity; while we rise in Insects to the greatest possible diversity, and even a diversity which presents an analogy with the character of concentration, observed in the various arrangements of their nerv-

ous system, compared with that of Crustacea. So that here we have another, and perhaps one of the best, indications, that Insects stand higher than Crustacea, notwithstanding we have the anatomical evidence to the contrary, which has been relied on. Now if upon these data we should attempt a classification of the class of Insects, let me in a very few words make it clear.

Insects have generally been divided into chewing and sucking Insects, and then into other families. Spiders have been separated as a class, and also all Apterous Insects.

Now, the Millipedes rank lowest, as among Insects they represent the form of Caterpillars or Worms. Next the Spiders, in which the concentration takes place, in which the head and thorax are distinct from the abdomen, but in which head and thorax are not separate, as in other insects indicating some analogy to Crustacea. Then, we would have those in which head, chest and abdomen are separated; but among them, place those in which there are chewing jaws lower; and highest the sucking insects. And curious it is, among those which chew their food, that we have the less perfect metamorphoses and many which are aquatic in their larval condition; also among them the forms are less perfect, inasmuch as in Neuropterous insects the parts of the thorax are only partially united, and the number of joints remain greater even in the perfect insect; while in the sucking insect, the parts of the thorax unites in one mass, distinct from the head. In the Butterfly, we have, the evidence in the earliest larval condition, that the Worm is an aerial animal, rising above the other insects. And with these data I think I have shown that I am not wrong in considering the Insects as highest, if we judge upon entomological grounds and not upon other evidence.

LECTURE VIII.

I hoped to introduce another subject, which is connected with the history and metamorphoses of Insects; but my time is so short that I scarcely dare to mention it, only as connected with these investigations. I mean, the singular peculiarities of many insects who live in large communities, consisting of individuals of different kinds, combined in various numeric proportions, among which there are not only Male and Female, but also another kind of individuals, differing from them, called Neuters. In those communities, individuals live in various combinations; there being, for

instance, in a bee hive, one Female, a Queen, as she is called, a few hundred Males, and thousands of Neuters, living together in one community. The proportions are somewhat different in other species—the Wasps, Humblebees, &c. &c.

These facts, which are well known to Entomologists, and all those who have become acquainted with the growth and education of Bees, show that the ideas which are generally entertained about the specific distinctions and the characteristics of species, are not altogether correct.

It is not throughout the Animal Kingdom that

species consist of individuals of two kinds; and to know those two kinds, is not sufficient to form a correct idea of the species. There are species in which individuals of various kinds are combined together, and in which the combination, in proportion to the numbers which are constant, constitute an additional character of the species. And for those, we must enlarge our notion of specific limits, and introduce elements which are generally overlooked.

But I proceed to the illustration of the class of Crustacea. These animals constitute, as they are now circumscribed, a very natural group; though it may be very difficult to assign general characters to it. And, indeed, on trying to find a practical trait of character, a combination of structural peculiarities, which should exclude any other animal, and combine together all the Crustacea, I have strongly felt that these animals were now combined as they are, not from any anatomical evidence, but from the very reason on which I insist as the foundation of classification; namely, from various hints about the growth, the mode of formation, and the transformations of their species.

They are so heterogeneous in their external aspect, as scarcely to indicate animals belonging to one class. Who would suppose such a congregation of large shells, (here the Professor exhibited a large bunch of Barnacles,) to be Crustacean—to have an animal allied, for instance, to the Horse-Shoe, or to the Crabs, Lobsters, Shrimps, and the like. Nevertheless, it is certain, from what we know of the metamorphoses of the Barnacles, that they, too, as well as many Worm-like Parasites, belong to the Crustacea.

The importance of Embryological studies, for a correct understanding of the true character and classification of animals, is so plain and so obvious in the class of Crustacea, that I beg to be allowed to illustrate more extensively this class, in this respect, than I would otherwise.

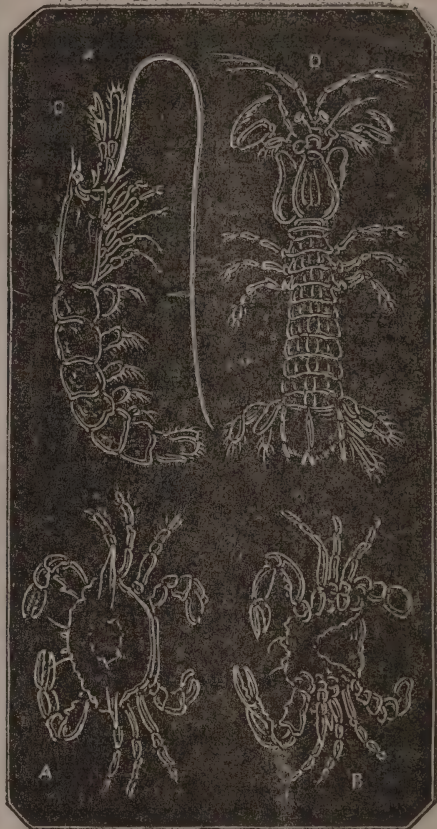
I would begin this, by pointing out some peculiarities in their form, which have reference to the changes which these animals undergo during their metamorphoses. Plate XVII represents various animals, all of which belong to the class of Crustacea.

In Plate XVII, fig. A, is a Crab (*Eupa dicantha*) seen from above; and in Fig. B the same as seen from below. You may notice the number of legs. They are in pairs—the anterior pair of which constitute powerful claws; the others being terminated by a simple joint at the end. The body is so contracted that the longitudinal diameter is shorter than the transverse diameter. It is a peculiarity of almost all Crabs, that their longitudinal diameter, if not shorter, is scarcely longer than the transverse.

Another peculiarity is, that the tail itself is short and bent under the main part of the body. (Plate XVII, fig. B).

The main body, which is neither a head nor a

[PLATE XVII.—CRABS AND SHRIMPS.]



chest, but which is simultaneously both, and on that account is called cephalo-thorax—the head-chest—contains the main mass of organs; the nervous system, the alimentary canal, and the heart as well as the respiratory organs, which are in these animals attached to the legs. This peculiar, contracted form will presently be found to have reference to some changes, which are noticed in the growth and metamorphoses of Crustacea; and are therefore essential.

On the anterior portion of the body, there are thread-like appendages, called antennæ or palpi. Of those, there are two pairs; one an inner pair, and the other an external pair; and sideways from those, are eyes. They are, in these Crabs, (Plate XVII, figs. A, B) placed in a little depression on the side of the shell, so that they cannot be seen in the position in which this animal is drawn in this plate. To see the eyes, we should look into the face of the animal. Between the eyes and palpi are the jaws, consisting of a very powerful apparatus of moveable appendages.

The position of the main organs is the more important, as it is reflected by the external covering; so much so, that from the outside, in various spe-

cies, the position of the heart can be recognized by definite outlines. These outlines in the shell (Plate XVII, fig. A) cover the position of the heart. This other outline indicates the position of the gills. This becomes possible, from the fact that those organs, though soft, are earlier developed than the shell, which is modeled over the organs.

The position of the gills is important on one account, being always connected with the legs; though they appear to differ widely in their position in various Crustacea. Where they are covered, they are attached upon the thigh, the shield extending over their point of insertion.

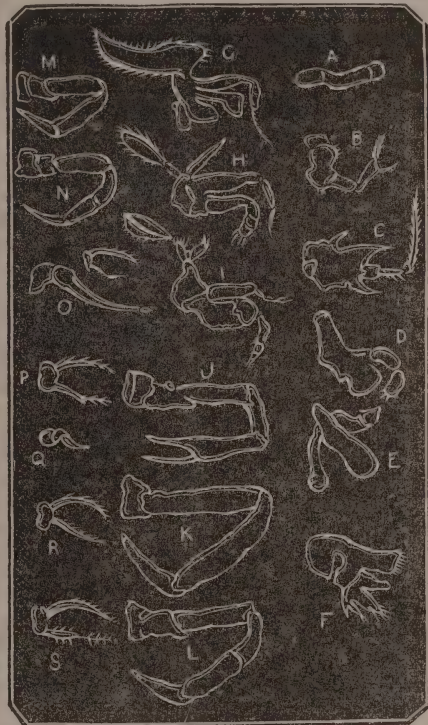
In other Crustacea, the gills are external—they are attached to the external joints of the legs, and seem to present an entirely different connection from what we observe in the Crabs. But the moment we go to the bottom of the question, we see that here also the respiratory organs are connected with the leg, only that they are from the upper portion, and covered by a shield, as it is developed.

In those Crabs, the nervous system presents a very interesting arrangement. Above the alimentary canal there is a first mass, which gives threads for the head proper, a kind of brain; a ring around the alimentary canal connects this swelling with the other swellings; but these posterior swellings form only one uniform mass in the centre, from which threads go to all the rings of the chest and their appendages. And this position, this concentrated arrangement of the nervous mass, is observed in all Crabs. In other Crustacea, the nervous centres under the alimentary canal are more or less scattered, and correspond directly in their position to the rings which they furnish with nerves. This structure of the nervous system plainly shows that the Crabs must be considered as ranking highest among Crustacea, if we remember what has been observed in the Caterpillar, in which, during its metamorphosis into a higher form, the nervous swellings were observed to concentrate gradually more and more into compacter and fewer masses. [PLATE VI page 41—LOBSTER.]

Let us now compare these Crabs with a Lobster, (Plate VI) or with a Shrimp, (Plate XVII, fig. C) a species of Shrimp which occurs in the Southern States, called *Peneus setifer*. The general arrangement of the parts is the same as in Crabs. Here we see first, the cephalo-thorax covering the main organs, and the anterior pairs of legs, covering also the mouth, and from which, on the anterior part, arises the peduncle for the eye and those appendages called the palpi. Next, we distinguish the tail, which is continuous with the head-chest, and forms a large part of the body; a portion of the body, which is as large as the cephalo-thorax, or even larger, and which can be curved forwards, but which is never permanently bent under the cephalo-thorax. Such an arrangement of parts is also observed in the Lobster, (Plate VI) which does not differ materially in its structure from

what we have noticed in the Shrimp. The various rings which constitute this cephalo-thorax and the tail, are equally provided with moveable appendages, which are represented separate in Plate XXI. In the head we notice a short peduncle, (Fig. A) terminating with a compound eye, consisting of thousands of little lenses, each of which has a crystalline lens, a nervous thread, and really is a compound eye. Next, we have those two sorts of palpi represented in figs. B, C. Next we have six pairs of horizontal moveable jaws, (Figs. D, I,) three of which are more powerful perhaps than the others, and constitute what are called the jaws (Figs. D, F); whilst the three others are called jaw-feet, from their close resemblance to the legs in many of these animals.

[PLATE XXI—APPENDAGES OF CRUSTACEA.]



The three first pairs, which are near the palpi are properly called jaws; and the three following pairs are called jaw-feet, (G, H, I). They are called jaw-feet, for having internally, like the legs proper, appendages which are modifications of the apparatus which supports the gills proper. These appendages, however, (Figs. G, H, I.) instead of being complicated gills, have only fringed membranes, extending backwards, without performing respiratory functions. So that, in these parts which surround the mouth and act as jaws, we have the same connection between the respiratory organs, as that we observe in the legs under the chest.

So that, notwithstanding the functions of these parts, which are used to crush food before it passes into the alimentary canal, we see that they are a modification of the same appendages which on the side constituted simple legs. Here, jaws and legs are really modifications of one and the same type of appendages.

But the chest is not one continuous mass, (Plate VI). It consists of several rings, united in the full grown individuals, but distinct in the young, and still distinct on the lower surface of the adult. These transverse ridges, (Plate XVII, fig. B) which are noticed between the legs, indicate the joints, which, by their re-union, constitute the chest, or cephalo-thorax. And so we cannot wonder that there are as many pairs of legs as there are joints united to form the cephalo-thorax. These five pairs of legs of the chest are figured separately, (Plate XXI, figs. I, K, L, M, N).

But, are we allowed to consider the cephalo-thorax as consisting simply of five joints, and one for the head? If it be true that every joint can have but one pair of moveable appendages, then we must admit that the head, however contracted, is the result of the re-union of nine distinct joints. The eyes, the palpi, the three pairs of jaws, and the three pairs of jaw-feet. And indeed, so many transverse divisions may be noticed in the interior of the chest, in its anterior extremity, when examined closely; it can scarcely be doubted, therefore that it is out of so many joints that the cephalo-thorax has been formed.

At the posterior part of the body, under the tail, we have other appendages, which assume the shape of branched threads, as represented in Plate XXI, figs. O, P, Q, R, S. These are modified legs, which are not used in locomotion, but to which the eggs become attached when they are laid, and as they remain suspended to the lower side of the tail, they are carried about by the female Crabs till the young are hatched. The fin-like appendages at the extremity of the tail, (Plate VI), are still other modifications of legs; and so, throughout the longitudinal axis of such an animal, whatever shape its body assumes, whether in Insects or Crustacea, the appendages used as legs or as jaws, are only modifications of one and the same sort of organs.

It was important to come to this conclusion, in order to be allowed to compare the various appendages which were noticed on the side of many of these other Crustacea, (Plate XVIII). For instance, in Squilla, (Plate XVII, fig. D), we have a kind of claw, of a very different nature. It is no longer as we see it in the Crab, but it is the terminal joint which is bent over the preceding one. So that the claw here would resemble the motion of my arm pressing against the shoulder, and forming a forceps, not by the antagonistic action of two articulations moving against each other, as in the Lobster, but by the bending of the last joint against the preceding one.

Many other modifications of these appendages are noticed on the sides of the body of Articulata; but the time will not allow me to give all these details; I merely refer to them for the sake of further comparisons. Let me only show that here in Stomapoda or Amphipoda, there is a difference of arrangement in plate XVII, fig. D, and plate XVIII, different from what we have in Crabs and Lobsters. The gills are entirely internal in Lobsters and Crabs; in the Squilla they are below the rings. Is there an essential difference in such a position? No, there is not. If we look at the embryo Crawfish, as it has been figured by Rathke, we shall know that the shield, or the external covering, is gradually modified by the development of the shield, which grows successively over the gills. The gills are external where they are attached to the lower joints of the legs, and are not different in their nature, but only modifications of one and the same type.

All the Crustacea belonging to these two groups, or rather to these three groups—the Crabs, the Lobsters, and the Squilla—are among the larger of the class. The other types, represented (Plates XVIII, XIX, and XX) are almost universally small—some even microscopic. In the Amphipoda (Plate

[PLATE XVIII—LOW SPECIES OF CRUSTACEA.]



XVIII, figs. A, B, and C), we have a structure resembling the Shrimp in its general outlines; but in the eye, we have no longer a peduncle. The eye is sessile—that is to say, it does not rise above the surface of the body upon a peduncle.

In the others, Decapoda and Stomapoda, the eyes proceed from a moving peduncle, and are provided with the peculiar apparatus for seeing.—Such eyes are, therefore, moveable upon the joints of the peduncle; but in these Amphipoda the eyes are flat upon the shield (Plate XVIII, fig. B). You see that there is a diversity of legs among them, and a peculiar kind of claws in the anterior part—various appendages performing at the same time the function of legs and gills, and the tail similar to that of Decapoda (Plate XVII, fig. B). One modification, however, will strike you. There are no longer many joints united to form a cephalothorax, but all the joints are nearly equal. The head constitutes only a joint similar to those of the rest of the body. There is no concentration of legs in distinct regions. The number of these animals which occur in this vicinity is very great; but they have, by far, not all been described. A few only have been mentioned in Dr. Gould's Report. Even genera which have not been described at all, occur in the harbor of Boston. Here, for instance (Plate XVIII, fig. C), is one of the new species, a new generic type, which is very beautiful. It is a curious fact that among these animals there is such a variation of color. I have had a good many of them drawn and painted, in order to collect all the variations of colorations which exist.

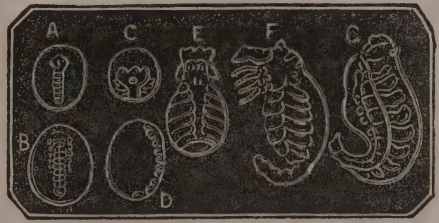
It is scarcely possible to find two specimens which agree in color; and many differ in the distribution of color so much, that if they were brought from different countries, and if it was not known that they lived together, Naturalists might arrange them as different species. In various individuals of the same species, (Plate XVIII fig. A) we find some are red, and others (Fig. B) green, others bluish, and others still, with every variety of color. To this fact I shall call again your attention hereafter.

We have (Fig. E) others still different, in which the different joints are so slender as to form an elongated figure with outward appendages to it.—The middle appendages are very simple; the anterior ones have claws, while the posterior ones are mere simple legs. But on the whole, they come near to the Amphipoda, (Plate XVIII, fig. A) As the legs, however, show some modified combinations, they have been considered as a peculiar family, under the name of Loemodipoda.

In some Crustacea of another form, (Plate XVIII fig. D) the rings are also not combined in distinct regions, and the eyes arise equally from the level surface of the shield; but the legs are uniform, and the uniformity goes on, increasing as we proceed lower down, to the various forms of this type which comprise the Isopoda.

All the Crustacea of which I have spoken, have one common character—a thin calcareous shell;

[PLATE I—GERMS OF SCORPION.]



whence their common name of Malacostraca is derived. Those of which I am now to speak are different in this respect, and have been called Entomostraca. Some of them (Plate XVIII, figs. G and H, and Plate XX, figs. F and L) are Parasitic Animals, in which we observe two long appendages, or ovaries, hanging down from the posterior joints. The body in the Entomostraca is simply protected by a horny shield or envelope, lining the back. There are some (Fig. G) in which the body is elongated, in the shape of a Worm, and in which the joints are almost entirely gone; so much do they differ from the common character of Crustacea; and indeed, in such an animal as the *Lerneæ*, (Plate XX, fig. L) there is no joint at all to be distinguished; there are not even gills to be observed; there are no legs to be found in any part of the body; there is no heart; no one of the leading anatomical characters of this class of animals is observed in the *Lerneæ*; and nevertheless it is a Crustacean. It is one of those Crustacea which have been long known in their later condition of life, when they have become attached Parasites, but which have not been known in their earliest stages of life, when they are free, moving, independent individuals, with all the characteristics of other Entomostraca and similar Crustacea. These young, however, have the structure of Crustacea, inasmuch as they have fringes, appendages to their rings; inasmuch as there is a nervous system, presenting the arrangement of the nervous system in the Cyclops. But, when they have been freed for a certain time, they become attached, and are then Parasites, and undergo a most remarkable retrograde metamorphosis, by which they lose all the peculiarities of their structure, sink to a lower condition of life, and producing a great number of eggs in this condition, finally die by a peculiar kind of bodily decay, as it were, which we nevertheless cannot consider as a decay, as it is in this curious stage of these animals that their eggs are most rapidly produced. It is really, as Rathke has considered it, a true retrograde metamorphosis in after life. But it is remarkable that there should be animals belonging to the class of Crustacea, which have so entirely lost the aspect of Crustacea; which have no one of their anatomical characters, and which, nevertheless, belong to that class, as is shown by their metamorphosis.

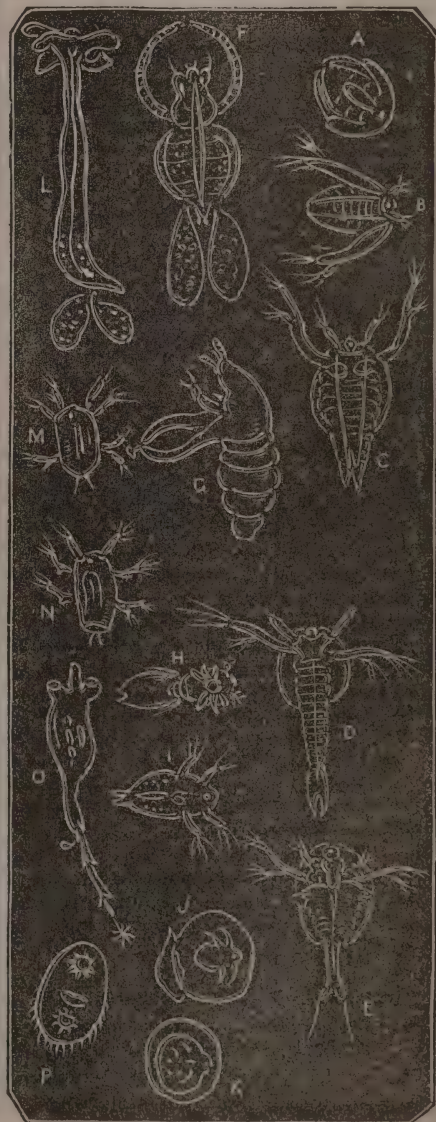
[PLATE XIX—YOUNG CRABS, SHRIMPS, BARNACLE AND CYPRIS]



We may say the same of Barnacles, in which in the final condition there is nothing of Crustacea in their external appearance; but which when young resemble common Shrimp-like Crustacea, to a very great extent, as we see by comparing a Cypris. (Plate XIX. fig. F, with a young Barnacle, fig. G.) There are several of these horn-shelled Crustacea which have been described as peculiar animals; for instance, the species figured, which constitute the genera *Foda*, *Megalopa* and *Cuma*, (Plate XIX, figs. A, B, C, D, E,) which are nothing but young Crabs and Shrimps. Their resemblance to *Cyclops*, or *Calanus*, (Plate XVIII, fig. F.) or to Cypris, (Plate XIX, fig. F) is however striking. Here is a species (Plate XIX, fig. F) of Cypris, for instance, which resembles, not only the other young Crustacea of figs. A, B, C, D, E, but even the young Barnacles (Plate XIX, fig. G) most remarkably. The young of a shelly animal, which in this early condition of life is a little, free, moving Shrimp-like Crustacean, with an elongated tail, with legs and respiratory fringes, having eyes in the anterior portion of the body, which is similar, in fact, to other young Crustaceans, and which, after it has grown

to a certain size, becomes attached, and is transformed into the remarkable Barnacle. Here are some more, of the curious Entomostraca (Plate XX) to which I shall call your attention. We have (Figs. A to E) one species, (Figs. F to K) another species. This latter one, resembles the *Lerneæ* in many respects; being attached by a sucker to the gills of fishes, on which they live, but having still a proboscis with jointed appendages, and having also indications of rings in the posterior part of the body, and having sacks of eggs hanging behind. In the other, *Apus*, (Figs. A to E) the body

PLATE XX—ROTIFERA, AND PARASITIC CRUSTACEA]



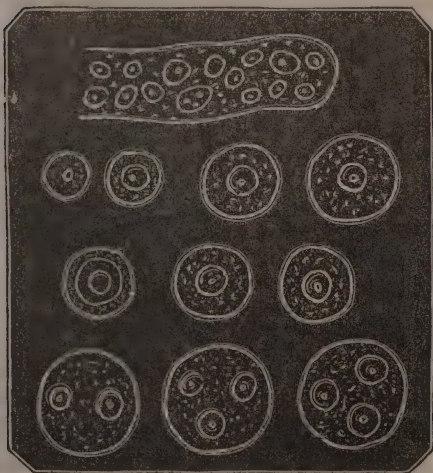
is free through life; but all undergo similar changes in early life.

The Horse-Shoe Crab, though large, and in many respects somewhat more complicated in its structure, belongs also to the Crustacea which have not a calcareous, but a horny shell, and are called Entomostraca.

From these facts, you may observe that Naturalists divide the Crustacea into two great groups; those furnished with a shield, like the Crab and the Lobster, called *Malacostraca*, and such as are not thus protected, called *Entomostraca*, which have only a horny envelope, and in which all the parts are less diversified.

I may mention more particularly one of these Entomostraca (Plate XVIII, fig. F) a species of *Calanus*, which has a peculiarity of being phosphorescent, and of presenting a peculiar kind of phosphorescence which I am not aware has been observed before. Here the nervous system, with the eyes, is the shining part of the animal; that nervous system being not only phosphorescent, but the substance of the nerves being of a highly red color. The arrangement of the parts is precisely the same as in the nervous system of the Crustaceans in general. A close investigation of this arrangement has shown me that there can be no mistake about it.

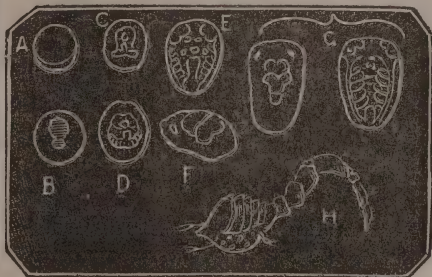
[PLATE XXII—EGGS OF PINNOTHERES.]



The embryonic growth of Crustacea has been extensively studied. We have had numerous monographic investigations upon that subject, which were made by the most eminent of the Embryologists of our day. Rathke, in particular, has investigated that subject to a greater extent than any one else. However, the earliest changes which the egg undergoes, have not been so completely examined. Therefore, allow me to call your attention for a few moments to the transformations of the eggs of the little Parasitic Crab, the *Pinnotheres Ostreum*, which is found in Oysters, and lives as a Par-

asite between the gills of this animal. The whole animal is so transparent that its growth and changes can be very easily investigated. And there we find eggs of various degrees of development, some exceedingly minute, which consist of a simply vitelline membrane, with an absolute transparent yolk, a small germinative vesicle and a germinative dot in the centre; a few granules are noticed in the yolk substance. Others will present the same appearance in general structure, when the germinative vesicle will be much larger, and the germinative dot also much larger, being swollen into a small vesicle. The same will be universally observed in a series of changes, where we notice that the germinative dot may grow much larger than it was before, and even form a hollow vesicle within the germinative vesicle itself; the yolk granules having greatly increased in quantity between the germinative vesicle and the vitelline membrane. So that here it is perfectly plain, that, the germinative dot can grow into a hollow vesicle; and from the condition of other eggs, we may be satisfied that there is a period when the germinative vesicle and the germinative dot may disappear, to give rise to the formation of another germinative vesicle containing more numerous granules; and that that vesicle may burst again, and give rise to the formation of two germinative vesicles with their germinative dots, or we may have three germinative vesicles with their germinative dots. And during this period of evolution of cells within cells, there is an increase of the mass of yolk taking place, an accumulation of granules growing, by which that egg finally assumes that degree of maturity, which precedes the first formation of a germ.

[PLATE III—EGGS AND DEVELOPMENT OF SHRIMPS.]



I have traced these eggs up to the moment when the yolk had become a mass of somewhat opaque, though not very compact yolk, and the first rudiments of an embryo were formed, as a disc on one side of the egg, growing around it, and presenting all the changes which have already been described by Rathke and Erdl, as occurring constantly in the growth of Crustacea, and to which I will now allude, referring to the species which he has figured.

The earliest condition of these germs in *Palæmon*, (Plate III, fig. A,) after the egg itself has un-

dergone all its changes, is the formation of a layer of more animated substance, the beginning of the young animal. We have here (Plate III, fig. B) the germ as it flattens out at one end and is contracted at the other part, divided as it were into two connected discs, the larger assuming afterward another form (Fig. C), the smaller one growing laterally, when soon it is observed what has become of these two extremities of the expanded disc (Fig. D). One will be the head end of the germ, and the other will be the caudal end of the germ. Those serratures upon the posterior extremity of the animal, represent the divisions in the animal layer, in the blastoderma, or germ, which will give rise to the joints or rings of the chest; while the anterior disc will represent that part of the body which properly forms the head, growing larger and larger; these flat discs are drawn backwards, forwards and on the side, so that it gradually surrounds the yolk, having assumed a more elongated shape (Fig. F) leaving the mass of the yolk free at the dorsal side, so that when seen from above (Fig. G), you have the margin of the animal in sight, which is rolled over the yolk. We have also here the eyes, which are forming at the anterior portion of the germ; and also the indications of the formation of a heart.

But from below (Plate III, fig. E,) we see how the lower surface is changed; the formation of those parts which will represent the mouth, is seen, and also the formation of those parts which will represent the legs, and in addition, the parts which will represent the tail. And those separations of different joints become gradually more and more distinct, (Fig. G,) so that upon close examination, you may find that the germ is now a little animal, which soon escapes under the form of fig. H. Here we have the young, which rises from such a transformation; and this young is the young of a *Palæmon* of the character of Plate XVII, fig. C. The young as it is hatched represents the figure which is a general characteristic, not only of the Macrouran Crustacean, but it has more particularly the form of those Entomostraca which have been described under the name of *Cuma* (Plate XIX, figs. D and E) I have traced many of those which occur in Boston harbor, of *Palæmon*, of *Hippolyte*, even of *Mysis*, and they all give rise to young which are species of the genus *Cuma*, belonging to the Entomostraca of Carcinologists; showing that there are still extensive grounds to cultivate in the history of Crustacea, and that they undergo metamorphoses. The subject of the metamorphoses of Crustacea has been discussed very extensively, Rathke denied positively that there are metamorphoses among Crustacea; while facts were collected in Ireland which showed distinctly that such metamorphoses take place.

Mr. J. V. Thompson, who has published many interesting investigations upon the lower Marine animals—the same to whom I have before referred

—and who discovered that the young *Comatula* had a stem in its earlier condition, was also the first to notice that the so-called *Zoea* (Plate XIX fig. A and B), were not animals of a peculiar genus, but that they were the young of Crabs—of Crabs of similar form to that figure, (Plate XVII, fig. A.) Captain Tuckey of the British navy, observed similar changes. He saw the transformation of the egg into those entomostracal germs, and further changes, which left no doubt in his mind that the Crabs underwent the above described metamorphoses.

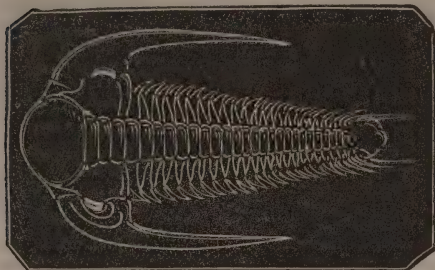
The objections of Rathke arose from the fact, that the Crawfish, a Crustacean, in which he studied that embryology, does not undergo extensive changes of form during its embryonic growth. The young Crawfish resembles very early the perfect animal; but by correct investigations this eminent Embryologist was misled; though he afterward acknowledged his error with reference to the investigations of Thompson, in the most liberal and generous manner. These metamorphoses have been traced extensively in other Crustacea. Zaddach has published a monograph, in which he has represented the changes which this animal, *Apus*, (Plate XX, figs. A to E) undergoes, from its primitive formation in the egg, up to its perfect condition, (Fig. E.) In the beginning (Fig. B) it has but few appendages; and afterwards, others successively, more numerous, are added underneath. Here (Fig. F) is a diagram of another animal, the *Achtheres*, in which similar embryonic changes have been observed. First, there, are also but few appendages, but afterwards several pairs have been added to form the various appendages which exist in the adult (Fig. G.) How similar Rotifera are to these various embryonic conditions of Entomostraca, will not escape the observer, who is simply reminded of the existence of these microscopic animals, (Plate XX, fig. O.) They resemble most remarkably those Entomostraca in their earliest condition. But in their embryonic condition, Crustacea—even Crabs, as well as Lobsters have young which resemble perfect forms of those Entomostraca, beyond which certain Crustacea do not pass: We have thus direct indication that they should be considered as the lowest; and so would we place at the lowest range, all the Rotifera and these various kinds of Entomostraca and Parasites, (Plate XX and Plate XVIII.) Next, we would have the Malacostraca; and among them, those lowest, with uniform rings, which are not combined into distinct regions; and next, those in which the rings are also not combined, but the legs diversified, (Plate XVIII, figs. A, B, C, E); and above all, those in which the rings are combined in various ways, which are still more diversified, (Plate XVII.); placing the Lobster and Shrimp lower among them; but we should consider the Crabs (Fig. A) the highest of all, because in these the concentration has gone to the extreme, the tail which was

proportionably the greatest appendage, the longest and most developed part of the body, in the earliest condition, being now reduced to the simplest and lowest condition.

Such a classification agrees with the classification which has been introduced into our natural histories, from the general impression received from these animals. Guided to some extent by anatomical details, and also in some points by embryonic data, the arrangement proposed has been the same to which, from embryonic evidence, we would arrive. Only, there is an objection to be made to the division of Crustacea into two groups; Entomostraca, passing by transformation into Malacostraca, as can be directly ascertained in the case of *Cuma*, the young *Palæmon*. Therefore, that division cannot stand as a natural division. We must have a series of groups following each other, according to their embryonic gradation, but not two types of Crustacea; as the differences upon which this distinction rests present only degrees of one and the same thing.

But, there is another point in which the analogy of gradation with embryonic growth is most remarkably striking. It is the order of succession of Crustacea in geological times. Crustacea have existed from the earliest times. They are found in the earliest formations, and found in all subsequent beds.

[PLATE XXIII—TRILOBITE.]



The forms assumed are different. The oldest are the so-called Trilobites of several types (Plate V). There is a remarkable analogy between the forms of various Trilobites, and the outlines of the germ of Crustacea, as figured Plate III, the earlier stages reminding us of *Agnostus*, and the like, whilst the later agree more with the higher Trilobites; but the most striking resemblance is noticed on comparing these types with the embryo of the Entomostraca, as they are represented (Plate XX, fig. A) within the egg, before they are hatched; the divisions of the middle part of the body into three lobes, the

long, lateral appendages arising from the anterior extremity. Every point of the structure agrees. It is only, that in these ancient types there was a permanent state of growth—a condition under which this animal lived for ages, and reproduced its species; whereas, in our lowest Crustacea we find even such an arrangement in the earlier form only, as the beginning of a metamorphosis.

Next, we have in the geological series, Horse-Shoe Crabs. During the coal period, there existed several genera of Crabs allied to the Horse-Shoe, having the same general features. There are also species found in the Oolitic beds. If we trace the gradation of types, we find that these (Plate XX fig. A) the *Apus*, in their perfect state, are next in order. Those which undergo a retrograde metamorphosis or which agree with the embryonic stage of *Apus*, as Trilobites, being altogether the lowest. And so we have the Horseshoe Crab, which is the second type in the order of geological ages, ranking highest among Entomostraca; that is, above those which resemble the Trilobites.

During the deposition of the Oolitic and Cretaceous rocks, there existed a countless number of Crustacea, but all of them were Lobster and Shrimp-like animals. The earliest of all the Malacostraca is a long tailed animal, the *Palinurus Sueurii*, resembling Lobsters and Shrimps. And during all this time, we have only such animals—and not one Crab is formed until afterwards. But, during the later part of the deposition of chalk, we begin to find Crustacea with short tails, belonging to the type of Crabs. So that, in the order of succession of the more recent types, we have the same evidence that the arrangement which is proposed, from embryonic data, is also the order of progress which has been introduced into the character of these animals at different successive periods.

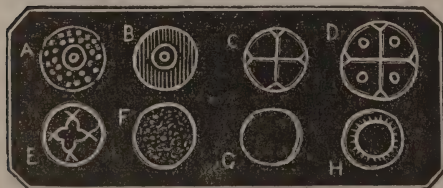
And I may add here, that the geographical distribution corresponds even to this gradation of types, as far as it is understood. Crabs, for instance, are not numerous on this shore. Few species occur here. In the Middle States they are more numerous. They occur more frequently and are very diversified in South Carolina; and still more numerous, in the tropics, where Crabs prevail over Lobsters and Shrimps. And, though these latter are extensively found in temperate regions, it may be said, that the lower orders of Crustacea (Plate XVIII, fig. A) are innumerable in the northern regions, and much fewer in the tropical regions. So that, in whatever point of view we notice this subject, we see one plan, one combination, one system, uniformly carried out.

LECTURE IX.

More than once I have alluded to the uniformity of structure of the egg, in its primitive condition, in all animals; thus showing that there is a common starting point for their growth, throughout the various classes of the animal kingdom. I shall now illustrate more fully the physiological process by which the egg, when matured, gives rise to the formation of a germ. I do not intend this evening to enter into more details than I have already given, upon the formation of the egg itself, but to illustrate the process by which the egg gives rise to a germ. This process has been traced in all classes of the animal kingdom; and it is found to consist of a very complicated series of changes taking place in the substance of the yolk, when it has reached a certain degree of maturity.

The condition, therefore, the first essential and constant condition for the formation of a germ, is the previous formation of an egg, and its being matured to a certain degree. The size, the degree of maturity, and changes which the egg itself undergoes before the germs are formed, vary in different classes. I will not allude to that point at all, but only take now the germ as it is forming within the egg, when the yolk has grown to a certain size.

[PLATE XXIV—EGGS OF PLANARIE]



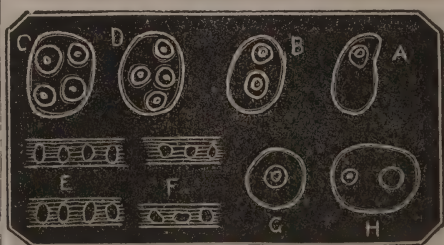
I cannot, however, omit mentioning a very curious mode of ovulation which is noticed in some Worms. When, some months before the laying of the eggs, we observe the ovary of the *Nemertes*, we see in their interior, oblong, bottle-shaped pouches forming, which fill with yolk substance, that gives rise to the eggs. When these bottles have attained their whole development, that is to say, when they are completely filled with yolk substance, a new process is introduced in them.—The substance groups itself around several centres, and forms a series of little spheres, whose number varies. These are the eggs; eggs which soon have a germinative vesicle, and within it, a germinative dot characteristic of the eggs in general.—When this second progress is terminated, the bottles are laid, under the shape of a chain, and the

eggs are thus contained in a transparent substance of shapeless appearance.

After the laying of the eggs, another series of transformations is produced, as we shall see presently. Almost the same changes occur in the *Malacobdella*, which is a Parasitic Worm found in the Clam. There, also, we have observed yolk bottles, as also the successive formation of the eggs. Here there is no ovary proper; we have found the bottles distributed in the whole body around the intestinal canal. Some contained only one egg, and some not yet condensed yolk substance; others contained two eggs; others three, four, and even a greater number were formed, until the whole yolk was exhausted.

Plate XXV represents some of these phases.—In the *Planarie* the mode of formation of the eggs is the same, except the bottles.

[PLATE XXV—EGGS OF MALACOBDELLA]



Let us return to the egg, when it is about entering another series of changes. In Plates XXIV and XXV, we have eggs of different animals, in which the process of the formation of the germ is represented up to a certain degree of its growth. The primitive egg consists, as you remember of a vitelline membrane containing yolk, and within this yolk a germinative vesicle, and within that a germinative dot, as shown in Plate XXIV, A, B. The yolk becomes gradually more and more condensed, thickened, and more and more opaque; and at that epoch, the germinative vesicle generally disappears; the germinative dot disappears also, and new changes begin to take place within the yolk.

It has been questioned, whether the germinative vesicle and the germinative dot precede, or follow the formation of the yolk substance. There are examples of ovarian eggs in which this vesicle and this dot are very distinct, as also the yolk membrane, at the time when the vitellus is yet very thin and transparent in the sphere of the egg. We have seen this vitellus increase and fill up the whole

space and condense around the germinative vesicle. So that there was no more possibility of doubt that the vesicle and the germinative dot did exist there before the vitellus. At other times, the germinative vesicle alone has been observed in the developing eggs. There are other instances where the ovarian egg presents neither germinative vesicle nor germinative dot during the formation of the yolk. This shows that even the question of the fundamental structure of the egg, in order to be solved, calls yet for minute and serial researches.

In the interstices of the granules or little cellules which compose the vitellus, is contained a transparent liquid more consistent than water, since it resists a certain pressure. When the egg is formed this liquid tends towards a centre and agglomerates itself there under the form of a transparent sphere, the appearance of which precedes the ordinary phases of the dividing of the yolk.

Whether the progress is the result of the mixture of the contents of the germinative vesicle and the germinative dot; or the changes are introduced simply owing to the fact that the egg has arrived at its maturity; whether it relies simply upon the yolk to undergo those changes, is a point which it is impossible to decide at present. Generally, when the yolk undergoes the first change by which the germ is formed, the germinative vesicle and the germinative dot have already disappeared; but in some instances, the germinative vesicle and the germinative dot have been observed within the yolk, when another mass, (the clear sphere) which generally appears after those have gone, had been formed in another portion of the egg, as represented in Pl. XXV, fig. H; so that changes which have been known to be connected with the first formation,—changes giving rise to the germ—such modifications are observed in the yolk when the germinative vesicle is still within.

Therefore, it cannot be absolutely said that the bursting of the germinative vesicle, and the mixture of the substance contained within it, is properly the cause of the changes now taking place.—It may have an influence upon the yolk, by which those changes are accelerated or facilitated; but that it is properly the cause, cannot be maintained.

Well, to understand all these changes which take place within the egg, they must be conceived as successive modifications of substance. We know that one sort of egg will only give rise to one sort of animal. Therefore we must admit, that as an egg of one kind gives rise only to one sort of animal, there must be an immaterial principle presiding over these changes, which is invariable in its nature, and is properly the cause of the whole process.

But now the changes which take place in the yolk vary in different classes of animals. In some they consist of a division of the yolk, which is

successively repeated and repeated, till the whole mass of the yolk has been so much subdivided as then to consist of innumerable little masses, arising from the subdivision, from the repeated subdivision of the primitive mass into successively more and more numerous parts. In others, the division is only partial. On one side of the yolk there is a depression formed, which does not penetrate across the whole mass, and then another, which will be formed at right angles with the first, thus forming four partial divisions; and that being repeated, the surface of the yolk, on one side of this mass may be divided into little fractions, though a great portion of the yolk takes no part in this process of repeated division and subdivision. In many animals the division of the yolk is most wonderfully regular.

The dividing of the yolk is probably a general phenomenon, appearing in all eggs, though observation has not revealed it to us in all classes with the same certainty. Its generality, however, is difficult to trace at present; as its various modifications have not been reduced to one common type: however, the fact is already ascertained in the class of Mammalia. In the Birds, the size of the eggs has been an obstacle for this kind of observation. It has been noticed in the class of Reptiles, and in that of Fishes. I have already mentioned the difficulty which observations encounter in the class of Crustacea and Insects; in regard to which the data upon the dividing of the yolk are deficient, although it has been observed in the inferior Crustacea. It is easily traced in the Worms and Mollusca; indeed it is nowhere easier to observe it, than in these two classes of animals. The phenomenon of dividing of the yolk does not follow the same course in every class at the same stages of development. Perhaps it begins, in some cases, even before the laying of the eggs. This would explain, at least, why it has sometimes not been observed. The process is sometimes slow, sometimes very rapid; and in this latter case it may easily escape the attention of the observer. Nor must we lose sight of the fact that embryogenic science is a comparatively recent one, and in this department there remains yet much to be done—above all, with reference to the study of tissues. This should especially be acknowledged, if we consider that it is as late as the year 1834, when Schwann made the discovery of the uniform cellular structure of organic tissues, in the animal as well as the vegetable kingdom.

There are animals, (and it has been more particularly observed among Worms, among Intestinal Worms especially, by Dr. Bagge,) in which the yolk first divides into two halves, which subdivide and subdivide regularly till the whole mass of the yolk is reduced into minute uniform yolklets. The process of this division is also seen in Mollusca, especially among naked Mollusca; the whole mass dividing into two halves, forming two distinct masses. Next, each will be subdivided into two

so that the primitive mass of the yolk will be divided into four equal parts. And then those segments will be subdivided and subdivided, till the whole mass consists of small yolklets, each surrounded by a membrane.

But the subdivision is accompanied by a peculiar formation of other masses within those partial spheres. Let me show you some diagrams representing this process. In Plate XXIV, fig. C, we have the eggs of *Planaria*, in which the yolk is divided into four masses; and in Plate XXIV, fig. D, we have it the same under slight pressure, when four clear spheres are noticed within each of these segments.

In the next place we observe that besides the four great masses there are four small ones, rising in the centre.

Again we may observe in each of the small ones such a clear sphere, and when the subdivision goes on forming a greater number of these spheres, the whole process is repeated, the large one being greatly reduced, there being successively, 16, 32 or more. Such fragments are increased very regularly, and though many variations are observed, they appear in multiples of two or four, and so on. When it has gone on a certain time, instead of four small ones and eight large ones, or vice versa, there will be quite a number of minute ones, and all alike in size, and the process will be repeated till these divisions are so minute that it is no longer possible to count them, they forming a mass of little cells, filling the whole of the membrane of the yolk.

What those clear spheres within the yolk are, it is somewhat difficult to say, inasmuch as chemical analysis cannot reach them. The eggs are so small that their composition has not been examined. It is only with the microscope that we can reach these processes and determine the changes of form and substance which take place, by the various properties of these substances with reference to light.

The fact of their being more or less transparent will make some appear different, under the microscope, from others. And that is the whole ground upon which the changes can be ascertained.

The manner in which the division takes place when there are two forming, for instance, in the intestinal Worms, has been described by Dr. Bagge, as follows.

The primitive clear sphere in the centre is said to assume an elongated form, and then the centre to be contracted, and finally the two ends become independent by a separation of the middle part, so as to form two spheres; and then the yolk mass to agglomerate around those transparent spheres; and then a division to be formed in the vitelline membrane; and that to go on and to divide the vitellus into two spheres; and in each the same process having been repeated, to have transformed that into four. Assuming again an elongated form, and

then dividing completely, they go on and form four masses. But that clear spheres within do not always constitute or determine the separation of the substance of the yolk into more and more numerous masses, is shown by the example which I have quoted, where a clear space exists in the centre of an egg, and the division takes place across it. For instance, there will be such a mass as represented in Plate XXV, fig. H., and the division will take place, a clear sphere accumulating on one side of the mass, and the yolk condensing on the other side, and so on.

The fact is, that the subdivision of the yolk mass and the formation of these clear spheres, is a process which goes on simultaneously, but which cannot be considered as directly dependant on each other. In proportion as this tendency of the yolk to subdivide is manifested by a contraction of the mass, and the division of the spheres into two spheres, in the same proportion the substance within the yolk, which fills the space in the centre of the yolk, accumulates in spheroid masses, to give rise to partial spheres. And that being repeated, there are then numerous divisions of the yolk successively introduced, and having been entirely kneaded, as it were, by this repeated division, the substance of the yolk in process of time becomes a germ.

For instance, in the Worm from which the diagrams in Plate XXIV are made, the germ (Fig. A.) is a mass of very minute cells. Then from the surface of those cells rises vibratory Cilia. We know that cells can have vibrating Cilia on one of their extremities. It is observed in the full-grown animals, and it is observed in many germs, especially in Mollusks, that such vibrating Cilia, are formed on the external surface of cells and become an apparatus for locomotion, which Cilia are voluntary, ceasing to move at intervals, renewing their motion at other times and transporting the animal from place to place. But remarkable as it is, that the sphere is the fundamental form of all animals, so rotation is the form of the action of all animals when they begin to move within the vitelline membrane.

No sooner has the little *Planaria* (Plate XXIV) been covered with vibrating Cilia, than it begins to revolve upon itself; it has then a spherical outline, and undergoes a rotatory, constant motion in one direction to begin with. And when it has grown to assume a somewhat elongated form, by which the prevailing longitudinal diameter will be introduced, after that longitudinal diameter has exceeded the transverse, then it will change the direction. And as soon as it is hatched, then it will proceed in an onward and forward motion, which will be the motion that will characterize the animal; and then comes the bilateral symmetry which exists throughout the animal kingdom, even where it is concealed under the radiated form of so-called radiated animals.

A remarkable comparison might be instituted

between the embryogenic phenomena, as we have just described them, and what is known of the celestial bodies, in their combinations, upon an immense scale. First, we have primitive cells, combining and condensing to form the mass of the egg, like clusters of nebular stars. After the yolk has undergone the various phases which precede the formation of the embryo or germ, this new being with a spherical form, which is also the form of the primitive egg, begins to assume a rotatory movement, under the influence of life, as the celestial bodies rotate under the influence of universal gravitation. At last the progressive, onward movement is introduced, which characterizes animal life properly, and is the first step in the series of progress, which, in man, ends with intellectual freedom and moral responsibility.

But this form of the division of the yolk is not the only one which is observed among animals. In Fishes, for instance, we have a division of the yolk, which differs considerably from that just described. In these there will be first a transverse depression upon the yolk, so that, seen from above, the yolk will seem divided in two halves. And then it will be divided again at right angles, so that there will be two furrows at right angles, forming a division which remains superficial. So that in a profile view these furrows do affect the yolk but very little, and the whole mass below remains unaffected.

But only the superficial layer undergoes this change; the lower portion and the central parts of the yolk remaining unchanged, but being gradually introduced into the process—being gradually absorbed by that part of the germ which is already formed, and finally totally absorbed by the germ; or if not introduced into the substance of the germ as a part of its body, it is finally introduced as a sac from the lower part of the body into the digestive cavity, and is digested. So that we have all possible steps, from total division of the yolk, which is entirely changed into a germ, to a superficial furrowing giving rise to a germ which rests upon a modified yolk. In the first instance, by repeated subdivision, the whole substance of the yolk is prepared to become a germ; or, in the second, only a part of it is modified to form a layer upon the yolk, which grows and gradually absorbs the remainder of the yolk.

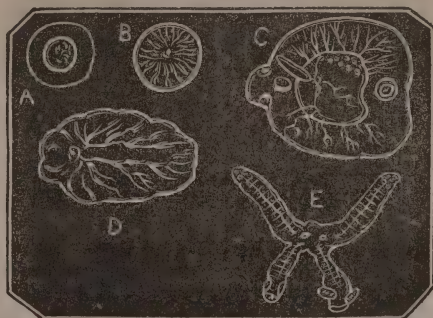
In those animals in which the division of the yolk is only partial, as in fishes, the divisions where they have been multiplied have nevertheless finally given rise to cells. In the beginning, those divisions are only separations of the superficial mass. But those masses not being entirely surrounded, do not form distinct spheres or parts of spheres; but at last, when they have repeatedly multiplied, then each particle is surrounded by a membrane, and thus transformed into a distinct cell. So that the germ, in whatever manner it is produced—whether by total or partial division of the yolk—is finally, when formed, constituted of

numerous small cells. The changes which those cells undergo—the manner in which additional cells are derived from the yolk, either by division or by evolution from those already formed,—constitute the phases of the embryonic growth of each animal. But it is by a uniform process of division that the germ itself is first formed. The degree of maturity which the germ has reached when it is hatched, varies extraordinarily. There are animals in which the germ is hatched in a degree of development which is so distant from what the animal will be finally, that it cannot be recognized, and that the type of the parent is not at all indicated even in the outline, in the form, or in the structure of the germ when born. There are other animals in which, on the contrary, the germ is not hatched before it has grown within the egg to assume the external forms of the mature animal, and has even attained to a very considerable size, in many of them.

It is perhaps from not having considered sufficiently those differences that so many mistakes have been made in the study of the changes which those animals undergo. Had it been supposed that animals were born in a condition in which they differ so widely from the parent, they might have been watched longer before they were described as distinct animals, on the sole ground, that they were free-moving. And we should not find that animals of the same species would be described under so many different names if this had been more generally known.

A great many larvæ of Worms are undoubtedly simply those small animals described as Infusoriæ; and I have myself seen eggs of Planaria give rise to some of these Infusoria called Paramæcium Anellides. Here, for instance, is one (Plate XXVI, figure E), remarkable for its sucker-like discs

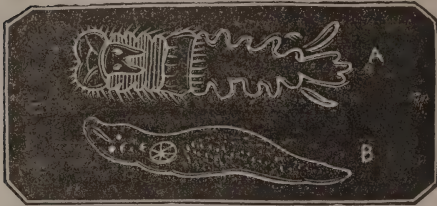
[PLATE XXVI—PARASITIC WORMS.]



and the Cilia by which it moves. The young Planaria resembles closely this species. And it is more than probable—it is almost certain—that a great number of those so-called Infusoria, are nothing more than the moving germs of Worms. Here is, for instance, a young Planaria, in which we have such a sucker, and in which the general form reminds us of the Infusoria very strikingly. (Plate XXVII, fig. B). The change which

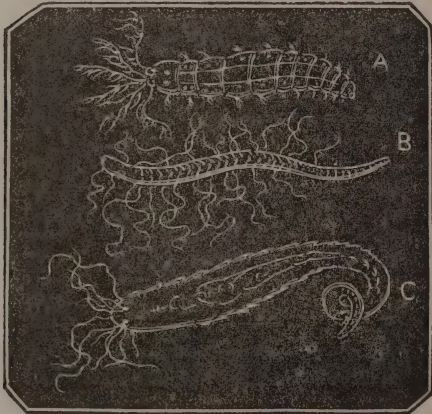
those germs undergo in various families of Worms seem to differ widely; and indeed, among Worms every where, there are types which are so widely different in their outlines as scarcely to afford characters by which to combine them.

[PLATE XXVII—YOUNG WORMS.]



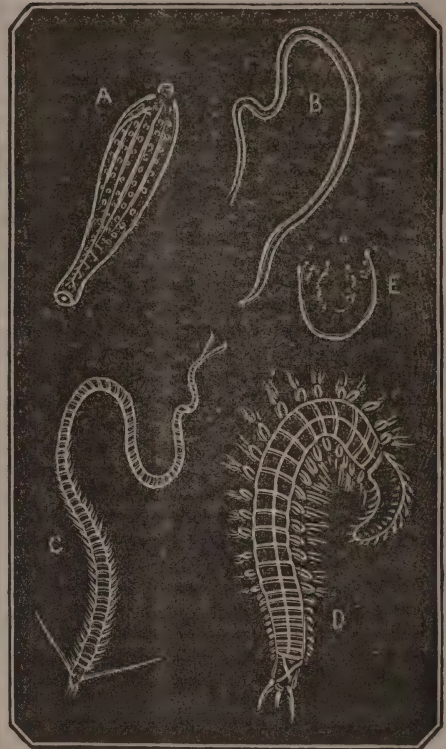
It will be a great difficulty to find Anatomical as well as Zoological terms to constitute into one class all these various forms, (Plates XXVIII, XXIX and XXX) and those which are represented there, (Plates XXXI and XXXII) Nevertheless, in tracing the intermediate forms, we are compelled to bring them into one and the same group.

[PLATE XXVIII—WORMS WITH COLORED BLOOD.]

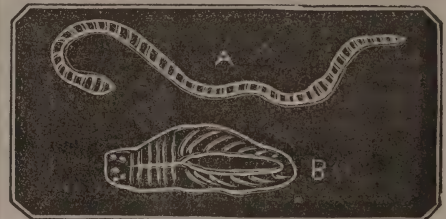


The class of worms, as I circumscribe it here, contains numerous and very diversified types, as well by their internal structure, as by their external form; so that it is difficult to assign to all of them common characters. The Intestinal Worms, formerly considered as a class by themselves, cannot be separated from the true Annulata. There are intermediate forms between the two groups—For instance the Trematoda, which are closely allied to Planaria, the Ascaris, which resembles Lumbricus, and so on. The Intestinal Worms, generally speaking, have their body naked; the Acanthocephala only have hooks of fringe-like appendages. Among Annulata there are, however, types which cannot be compared with any of the Intestinal Worms; as the Tubulibranchiata and Dorsibranchiata. Among these there are some in which the lateral appendages of the body are uni-

[PLATE XXIX—VARIOUS WORMS.]



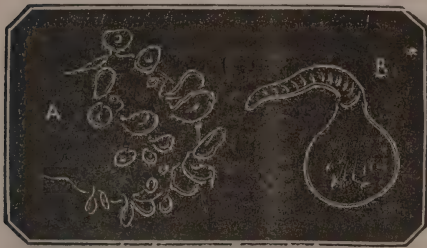
[PLATE XXX—EARTH WORM AND PLANARIA.]



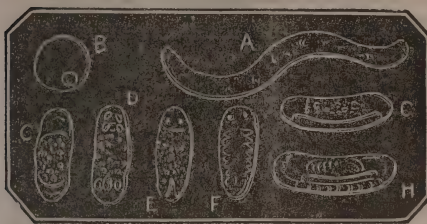
form for its whole length; in others, the appendages of the anterior, middle and posterior region of the body differ among themselves, and assume even an entirely different character. In some, the rings are generally provided only with a few stiff hairs, whilst the head is surrounded with tufts of respiratory fringes, and other appendages, in various degrees of development. Nevertheless, through all that diversity, there is a common type which can be easier understood than properly described or defined.

The development of the class of Worms varies according to its types. In some, the yolk substance, after having been indefinitely subdivided into homogenous little spheres or cells, assumes a rotatory movement, sustained by vibrating Cilia, which have been formed upon its whole surface. Such are the Planariæ, &c., &c., whose

[PLATE XXXI—INTESTINAL WORMS.]



[PLATE XXXII—INTESTINAL WORMS.]



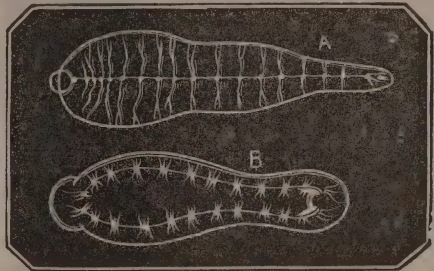
young are Infusorians. In others, the development resembles more that of Crustaceans and Insects, there being an animal layer formed upon the lower side of the yolk sphere, which surrounds gradually the yolk and encloses it, so that the navle is dorsal. Such a growth has been observed in a worm of the Leech family, which occurs in Fresh Pond, (Plate XXXIII) as well as in a marine Worm of the bay of Boston, belonging to the genus *Pasithæ*.

I wish only to make some remarks upon the various metamorphoses which the Worms undergo. Among the Intestinal Worms we have forms which are cylindrical, and which present no extreme divisions in the body (Plate XXXII, fig. C).

We have others which are also cylindrical, (Pentastoma, Plate XXXII, figs. A, B) but in which we have transverse ridges. There are very numerous forms of the kind, which are flattened as the Tapeworm. We have others in which the different parts of the body (Plate XXXI, fig. C), differ widely—the *Cysticercus*. There are others in which the articulations are still more distinct, and there are again others (Plate XXVI, fig. E) in which the articulations are scarcely distinct at all, but which constitute really compound animals, as there are always two united together—*Diplozoon*. There are again others, which are flat, (*Distoma*, Plate XXVI, figs. A, B, C, D) and entirely unarticulated, unless we should consider as articulations those folds on the margin, which can scarcely be considered so; but owing to the arrangement of their parts, particularly that of their nervous system, we find that they must be referred to the class of Worms. Indeed although these animals have been placed in a special class, owing to the fact that they are Parasites, they cannot be grouped together with all other Intestinal Worms, nor form a class by themselves. They have little in common with other Parasites, but this mode of existence.

In fact, Intestinal Worms constitute various types, of which the main common trait of character is to live upon other animals, rather than to resemble each other in their structure. But between *Planaria* (Plate XXX, fig. B) there is the most remarkable affinity. This is a *Distoma*. (Plate XXVI, figs. C, D) an internal Parasite, and we find that every thing agrees in the structure with *Planaria* (Plate XXX, fig. B). There is an alimentary canal, first a single tube, which divides afterwards into two, and from which arise innumerable branches ramifying in the substance of the animal.

The same structure exists in *Planaria*, an animal which has been referred to another class, but the resemblance is so great that it is now no longer possible to separate them; and very recently, Mr. Blanchard has proposed to combine them, under the name of *Aneurosi*; and previously Professor Owen had intimated the propriety of uniting them with those broad Intestinal Worms. Their nervous system agrees most remarkably, and agrees not only with that of other Intestinal Worms, but when properly understood, shows that the nervous system of the Intestinal Worms, though seemingly so peculiar, is really constructed upon the same plan as that of other *Articulata* in general. In *Articulata* in general, the nervous system consists of a series of swellings, as I have shown before (Plate [Plate XXXIII—Nervous System of Worms.]



XXXIII, fig. A). In *Malacobdella* (Plate XXXIII fig. B), and in all intestinal worms, the nervous system consists of a main mass about the alimentary canal, and two longitudinal threads extending along the two sides of the body, from which arise other threads. We have now only to conceive that the two parallel threads are brought nearer together, and combined in one continuous thread by transverse commissures, to have the same uniform system, which characterizes the higher *Articulata* in which those swellings are combined. We have again in *Planaria* the nearest possible approach to the nervous system of the Intestinal Worms, which really brings them much closer than they could be brought before, and combines them all into one class.

The manner in which these animals are found is very remarkable. The *Distoma*, as we have it here, (Plate XXXIV, figs. 2, 3, 4) lives as a parasite in the cavity of other animals—upon their liver—is very frequently met with in the cavities of higher

come their nurses, so that the nurses are born from another kind of Worms, living equally as parasites in those shells, and which are on that account called grand nurses, so that we have now three generations: Grand nurses observed in the early part of the year giving rise, by a series of development of their eggs to so called nurses, in which there are again eggs produced which undergo all the changes of a regular development, and are now born as Cercaria. And when these Cercaria have lived as free animals for a certain time, they undergo the changes which produce Distoma.

It is a remarkable fact, that the nurses of Cercariae bring forth a great many Cercariae, which remain as parasites; a great many of them being developed within the body of the shell fish, into a Distoma. We have, therefore, three successive generations which differ. The grand nurses give rise to a generation which resemble them in a certain degree, but not in every respect. And the nurses which give rise to Cercariae; and by metamorphosis the Cercariae are transformed into Distoma. How the grand nurses are formed, has not been observed directly. But it is known from other species, and it has been observed by Siebold, that the Distoma will mature eggs which will give rise to other animals similar to our grand nurses. These which will either grow within the maternal Distoma body, as in this form, (Pl. XXXIV, fig. B) where we have here Distoma, (Pl. XXXIV, fig. A.) and here, (Fig. B) we have its progeny. But as this progeny is so different from the parent, there cannot be a doubt but that at a certain period the Distoma lays eggs, and that there is a certain generation which resembles the first starting point of the animal. But whatever may be these changes, there will be always a period when the animal will lay eggs. And whatever may be the number of these intervening generations, there will be always a period when the animal will come back to the fundamental type of its species.

In the Tape-worm, a curious observation has been made by Prof. Eschricht, who has ascertained that the head, when it is furrowed by innumerable joints, will from time to time cast these joints, and at regular periods reproduce them. The joints present a remarkable uniformity of structure, in each joint there being the various apparatus—ovaries and other organs, which are developed in these animals.

So that each joint is, in certain respects, an individual by its structure, but remains united with its other joints, forming a series of articulations. In such a condition of things, we have certainly an approach to or at least some analogy with what we have observed in the Medusæ, which form those piles of individuals called Strobila, which become free and give rise to as many individuals. In Intestinal Worms such transverse divisions take place; the animal being free and each ring becoming as nearly as possible a peculiar individual forming a kind of compound animal, but in a dif-

ferent sense from what we have observed among Polypl, till at a certain period of the year, they cast these rings and scatter about the innumerable eggs which they produce. The quantity of eggs which are produced in each of these animals, and the quantity of eggs which are produced by each individual Worm, is amazing.

Prof. Owen has computed, that in one single full grown female Ascaris, there were sixty-four millions of eggs developed. Now as it has been ascertained by several Entomologists, that Intestinal Worms and their eggs have a more persistent life than other animals, we should not wonder that they have a chance to re-enter the bodies of animals in which they live. It is a remarkable fact, that Intestinal Worms are found generally in particular animals, and that the same species is not developed in every kind of animal, even if they live under the same circumstances. And now the chance which these various kinds of Tape-worms have of being introduced into animals of the same species as those from which they have been removed, is very great.

In the Fishes, for instance, the Parasites become a part of the food of the Fishes, and in this way they are transferred into the animals in which they live. Some of these Intestinal Worms have undergone the action of boiling water without being killed. Their eggs have been put under the influence of strong acids without being destroyed. So that we should not wonder, after such experiments have been made, that these animals, having been introduced into the alimentary canals of animals should live to grow and reproduce their species, instead of being digested.

The external Worms—such as live in the water or the earth—when they are hatched, present already transverse divisions. They early assume (Plate XXVII, fig. A) the shape of common articulation. Professors Milne-Edwards, Loven, and Kolliker have traced the changes of several of those Worms. But I see that I have scarcely time to state the leading facts of their history, and I must go on to another subject.

I shall now endeavor to show that there is a uniformity of type among the Worms, notwithstanding the external differences we observe among them. In these various external Worms (Plates XXVIII and XXIX) we may notice some in which there are no external appendages at all (Plate XXIX, figs. A and B)—for instance, the Nemertes—which is very common on these shores where I have first noticed several species. In Planaria there are also no external appendages (Plate XXX, fig. B).

In the earth-worm (Plate XXX, fig. A) we have appendages upon their rings, and although very simple, we have here the first step toward those complicated appendages which we notice in others. The complications grow out of modifications of those appendages themselves. Instead of stiff hairs scattered about, we may have a brush of

those hairs arising from definite parts, or the brushes may not arise immediately from the rings of the animal, but there may be vesicles into which the blood-vessels may run, and from which arise various hairs. And the manner in which these hairs are combined with the vesicles, and the vessels and the little hooks which may be appended to them, will constitute the most complicated appendages which can be imagined.

And, indeed, there are no animals in which the appendages are so complicated as they are observed to be in some of the Annulata. The anterior part may have one kind, the middle part may have another kind, the posterior part may have a third kind; or those of the head may be very prominent, and those of the posterior extremity of the body may be scarcely distinct. And these are the more remarkable, as we may find in the earlier condition of those animals that they are uniform. For instance, in this worm, (Plate XXVIII, A) which is a new genus, which I have called *Pleigophthalmus*, we have little brushes of stiff hair, and what is still more curious, a pair of eyes to each ring. And when the animal grows larger and larger these eyes vanish successively and there is only one pair left in the anterior portion of the body, and one on the posterior part of the body, and the intermediate ones are gone.

And here (*Cirrhatus*, Plate XXVIII, fig. B) are not merely eyes, but several colored dots to each ring, and along the whole body uniform vascular threads. Eyes which have a crystalline lens may gradually be found to pass to simple colored dots. This is the case, for instance, in the *Planaria* (Plate XXIX, fig. E), where we have no longer an eye, but we have a great accumulation of black dots upon the skin, some of which are larger than others, which can no longer be considered as eyes—which can no longer be considered as organs of sight—but which are doubtless an apparatus simply to receive an impression of the light.

These animals, without eyes properly, but simply with colored dots, must have merely impressions of light. The eyes are merely to concentrate the light. In *Cirrhatus*, we have simple vascular threads (Plate XXVIII, fig. B) to each ring; but in *Terebella*, which is the perfect state of the same animal (Plate XXVIII, fig. C) they are reduced to complicated gills behind the head. The vessels of the anterior gills, which occur in the anterior part of the body are indeed only modifications of these vascular threads. In the young animal (Plate XXVIII, fig. B), which has been described as a peculiar animal, under the name of *Cirrhatus*, we have the threads all along the body, and the posterior threads, gradually disappear first, and the anterior ones are branched and transformed into gills; and in the beginning there are vascular threads, one to each ring.

Let me now add another fact referring to this animal, that this *Cirrhatus*, when young, as it is

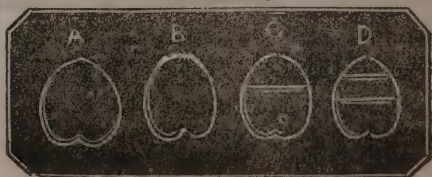
represented here (Plate XXVIII, fig. B) is phosphorescent. The adult, which has been described as a *Tersebella*, is also phosphorescent. But in the last, phosphorescence is only noticed in the long threads, but in *Cirrhatus* it is noticed all along the body. On close examination I have satisfied myself that the blood vessels are the phosphorescent apparatus. Some such threads separated from the body when acted upon by alcohol, or some other strong reagent, would throw out faint light when no other part of the animal would emit it. So that we have here an example of phosphorescence in a position of the body different from another which we have mentioned before—This phosphorescence proceeds from the blood vessels. We have had an example from the nervous system. I may quote others; for instance, some Insects in which the respiratory organs, those Tracheal organs, those aerial sacs, will emit light; and the facts are such that we perceive a connection between coloration and phosphorescence and sight, as there is between electricity, heat and light. The physical phenomena are parallel to the phenomena in the animal kingdom, only it is more difficult to show their connection; but I hope to show that there are at least among the Mollusca, some types in which it may be demonstrated that such a connection exists.

[PLATE XXXV—CATERPILLAR.]



Let me add one more remark, that the Caterpillar, with all its appendages, (Plate XXXV) should be compared with the Worms. What are the diversified hairs which are observed upon so many Caterpillars? They have been usually considered as hairs; but they are connected with the organs of locomotion and respiration, as in the Annulata. We should, therefore, institute upon the Caterpillar a regular comparison, to ascertain whether they are not in some respects analogous to the various appendages of the Worms. This comparison I have not instituted. It remains to be done; but I cannot help thinking, on noticing the close resemblance there is between the diversified aspect of Caterpillars and Worms, that in their analogies there will be also a type discovered, as it has been noticed in the appendages of Worms; and that Caterpillars will only be another modification more, of one and the same type.

[PLATE XXXVI—SYMBOLICAL FORMULÆ OF AR-
TICULATA.]



Having introduced in one of my preceding lectures symbolical formulæ for the three classes of Radiate animals, I deem it useful to do the same for the Articulata. Thus the symbol of the whole department will be an Omega (Plate XXXVI, fig. A.) representing the curious mode of formation of the embryo at the inferior part of the vitellus, of which the two sides arise in order to envelope the

vitellus. For the class of Worms we will have the same figure slightly opened at the summit, (Fig. B.) Fig. C, an Omega with a transverse bar, will represent the class of Crustacea, where two regions are already distinct. Finally, Fig. D, with two transverse bars, for the class of Insects, in which the body is divided in three regions.

LECTURE X.

When tracing the first formation and the growth of animals, there is one point, which never should be lost sight of. It is, that at various periods of this growth, the substance of which the animal consists gradually changes.

We have seen that in the beginning the germ consists of simple cells, derived from a modification of the yolk. Such is the first condition of all germs. Now, from this starting-point we may arrive at animals so complicated as Man.

In other animals, throughout the series of the animal kingdom, in which the most complicated structures are observed—in which structures very distinct are successively formed,—flesh, blood, nerves, skin, hairs, scales, and all possible structures so different as scarcely to be compared—how are these formed? Are they new things introduced during the growth of the germ—or are they only modifications, simple changes of one and the same fundamental element, modifications of the cellular tissue which characterized the germ when forming?

This is a question which can be answered by facts which have been entirely investigated by one gentleman, a young physiologist of Germany, Professor Schwann. Ten years ago he began to examine the subject of animal tissues, and up to that time it was believed that animals and plants differed widely,—that their substance had nothing similar,—that cells existed only in plants. Such was the condition of things in 1838, when Schwann, taking up the beautiful investigations which Schleiden had just published upon the structure and growth of vegetable cells, came to the conclusion that animal tissues consisted equally of cells, and that whatever may be the complication of this substance in the animal—whatever may be the external form of the various parts in the animal tissues—they all originate from cells, and are, after all, only modified cells.

In this absolute form, perhaps the results of

Schwann will have to be somewhat modified, but in the main all subsequent investigations have only gone to confirm his unexpected result, and at present there is no student in Anatomy, who has not seen these cells of animal tissues, who is not able to find them out, even with microscopes of a very inferior quality. But it required the sagacity of the able and persevering investigator whose name I have mentioned, to start such an investigation—to go through with it—to give it, finished, to the world, and then to remain silent for ten years through all the attacks he has had to undergo.

Since Schwann published the volume containing the results of his investigations, he has not been heard in the debates which are still going on upon this subject. It is a remarkable instance of confidence in his theory, and of a desire not to interfere with that which contradictory investigations might bring about. Still it is known by his friends that he is pressing on, and preparing new investigations, which may lead to as important results as his preceding labors.

His efforts now go to ascertain how these cells are combined to form individuals of different kinds. Indeed, he has undertaken nothing less than to investigate, if possible, the principle which combines those cells into individual cells,—to ascertain the nature of that power which we call vital power,—to find out what kind of influence it is which constitutes individual, independent and progressive beings.

I have delayed introducing this subject up to the present evening, because there is no class in which the cellular structure of animal tissues can be so fully and easily illustrated, as among Mollusca.—In their tissue when full grown, in their egg when forming, the cellular structure is perfectly plain and easily ascertained.

To what important results for Physiology the final investigations on this subject will lead, can scarcely be foretold now. For since it has been

ascertained that the animal tissues are, in their fundamental structure, identical with the vegetable tissues, we may expect that botanical investigation may throw as much light upon the animal kingdom, as the study of animals may throw upon the vegetable kingdom.

Easy as it has been to study the structure of vegetable tissues, so difficult has it been to ascertain their functions—to ascertain the working of the various organs in plants. The most different and contradictory opinions are entertained upon vegetable functions, upon the circulation of their sap, upon their respiration, and the action of respiration upon their fluids.

On the contrary, in animal structures the functions are easily traced. The combined action of various functions upon each other, can be easily ascertained. It was the structure—the intimate structure—which it was difficult to investigate. And now, by referring the result from one kingdom to the other, it is to be hoped that much more rapid progress will be obtained than before.

One unexpected result has already been ascertained—namely, that cells are properly the organs of living beings; that all functions are influenced by life, by the independent life of isolated cells. It is not the stomach, as a whole, which digests; digestion is influenced by the cells which line the internal surface of the stomach.

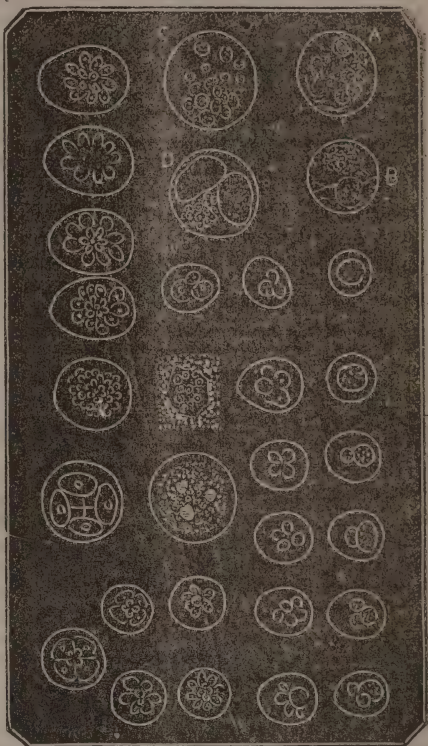
The life of individual cells may be compared to the action of several large organs combined into one system, as a whole. How much independence there is really in the life of individual cells, can no where be better shown than in some of the germs of Mollusks.

Let me for a moment illustrate the various figures which are represented in Plate XL.

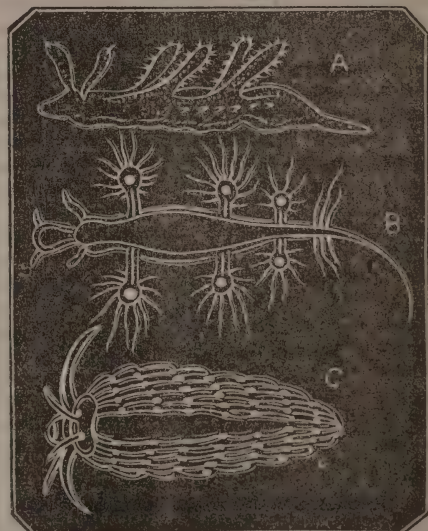
They show the changes which a Mollusk may undergo; a species of Eolis, a naked Mollusk, found in Boston harbor, of which there is a figure in Plate XLH. fig. C. Several species of these Mollusks occur in Boston harbor, and can at any time be obtained for investigation. Several eggs which contain a single yolk, are first noticed (Plate XL), and in the same plate are represented all the changes which the yolk undergoes in the process of dividing, up to the period when the whole mass of yolk is transformed into innumerable cells, as represented here.

The divisions of these masses are not always so regular as they have been described. In this Eolis, it does not constantly take place by a regular division into two halves. You see that the two halves are more or less different in their size; sometimes the division takes place into three spheres, two of which are smaller than the other, and not even equal among themselves. In others, there are three equal spheres; in others, four equal spheres; in others are four less equal; in others are five almost equal; and still in others, five, all of which are small. Many irregularities occur. There is no invariable rule.

[PLATE XL—CHANGES OF THE YOUNG EOLIS]



[PLATE XLII]



You may see in some other figures of the same, (Plate XL) that the process of dividing the yolk is very regular, there being first two, then four equal divisions, out of which may arise on one side four other large spheres, and on the opposite

side four smaller ones. We have still in another, less regularity. Four less spheres are formed, and between them two large ones, and two very small ones; and so on, by multiplying the divisions, we arrive finally at the state of the yolk, when it is composed of a mass consisting of many yolk cells, in each of which there is a clear sphere, as there is one forming in each division when the process of dividing the yolk has only divided the mass into fewer spheres.

About the time when the whole mass is reduced into small cells, there are vibrating Cilia coming out from the surface of some of these eggs (Plate XL, figs. A, B, C, D.)

But the most curious phenomenon which takes place is this: that the whole yolk does not constantly go on to form one single individual. But there may be instances when the mass of yolk which has been subdivided into cells, is itself divided into two, or three or more masses, which grow independently, several individual animals arising from one yolk;—several individual animals arising from one mass of yolk, which thus divides.—And in this process of the division of a whole mass into several individuals, there are isolated cells, which are separated from the main mass, and continue to live and to rotate by the agency of their vibratile Cilia with the main mass. And in such a case we have the wonderful sight of two or more germs, having been derived from the division of one unique mass of yolk, constituting two or three, or more individuals, each moving for itself and rotating with the others in one yolk membrane, and isolated cells which also rotate between. So that individual loose cells maintain for a time a separate life, and continue to live during the whole period of growth of the larger animals within the egg membrane; and those isolated, scattered cells die only when the larger germs, which will grow into perfect animals, have been hatched, or pressed out from the vitelline membrane.

Nothing could show more distinctly that there is independence of life in the cell than the fact of this isolation. But what the combining power is between those cells which grow and form individual animals, can scarcely be understood under such conditions. Whence the action of the vital principle which keeps the cells together, originates, escapes our intelligence. Indeed, nothing is more astonishing than to see that under slight pressure, such a germ may be resolved into loose cells, whose Cilia will continue for a short time to vibrate, in the same manner as a nebular mass seen through a powerful telescope may be resolved into individual stars, which nevertheless form a peculiar cluster of isolated bodies; similar to the cells with individual life, which constitute, as it were, similar clusters. And when they have gone beyond this period of life, then they have undergone a more intimate connection, which prevents their dissolving again; and then they go on constituting a new being. Then during the further changes, by

which they now assume the form of the parent animal, there are constantly isolated cells cast from the main body, which revolve for a short time, and then die. This process, which is exemplified here in the early condition of life, and under a simple condition of structure, is well known to take place in many animals, which cast their skin repeatedly during life, as the caterpillar; or Mollusks, which cast their external coating under the form of mucus; or other animals, which cast their hairs; or in our own body when the epidermis is cast and other cells are formed to take the place of those which fall off in the form of small scales. So that you see the remarkable phenomenon of the isolated cells of Eolis, is only what we have on a still greater scale in higher animals, where millions and millions of cells are constantly cast from the surface of full grown individuals.

These cells consist permanently and uniformly of an external envelope, a thin membrane containing a fluid, within which there is another vesicle called the nucleus, and in the centre of which, there is still another called the nucleolus, so that a perfect cell in its perfect condition is a sphere enclosing two other spheres, the innermost one being the smallest, appearing like a granule. In such cells as are represented in Plate XXXVII, we have figures with which we have been familiar from other illustrations. A cell in its perfect condition has the same structure as an egg in its primitive formation. Here we arrive at a most unexpected, but universal, uniform structure, not only of cells, but of the primitive substance of which new individuals are to be formed. What we call eggs in their simple condition, are cells of a peculiar structure, formed in a peculiar part of the body, destined to undergo peculiar modifications, by which the body is not enlarged, by which no particular function is performed, but by which a new individual is formed. So that in every point of view we find unity in the structure of animals, even in the structure, compared with the mode of re-production; the cells of which the tissues consist being identical in structure with the eggs by which new individuals are produced.

There is a question which may be asked, and to which I hope to give at least a partial answer. How are these cells formed? and how are these eggs formed? We have examined the mode of formation of the germs. Let us now examine the mode of formation of the eggs.

I have been fortunate enough to trace them through all their phases of formation in Mollusks, and I think there has not been a link in their transformation which has escaped my attention. So that the whole process of their multiplication has been directly observed. Tracing the formation of eggs will be tracing the formation of cells, the moment it is understood that cells and eggs have the same structure. When examining very young ovaries—for we must not take the egg when laid—we must not take them when formed within the ovary—we must not take even a full grown ovary—but

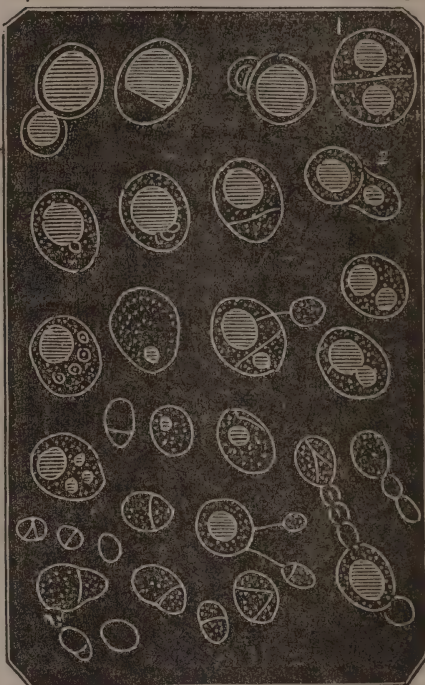
take the ovary when forming and examine what is produced. There we observe that the ovary consists of pouches (Plate XXXVIII, figure A)—folds of [PLATE XXXVIII.—OVISACS AND EGGS OF ASCIDIA.]



membranes, in each of which bottle-shaped pouches (fig. B) there are masses of eggs and other substances—granulated substances—and complete eggs in the larger ones. You may perhaps distinguish from the distance that in such a pouch (fig. A) which is circumscribed by a membrane, there is a mass of little granules and a number of eggs, each having a vitelline membrane with its germinative vesicle and its germinative dot. The smaller of these pouches contain the same elements. These smaller ones will contain fewer eggs. The still smaller one will contain also eggs, but they are not so well defined. And we may find some pouches in which there are no distinct eggs, but a bag full of uniform, clear liquid.

Here is the starting point. And if we examine under a very high power what is going on in these pouches, we may observe all the changes which are represented (Plate XXXVII) in these various figures. First a little bag is observed, but perfectly transparent and homogeneous. Others may grow larger, but still contain transparent homogeneous fluid. All these figures are represented under the same magnifying power. Then we may find one in which the membrane surrounding the liquid divides. This process of dividing is observed in the yolks when fully grown, giving rise to the embryonic cells; here it takes place to form numerous

[PLATE XXXVII.—FORMATION OF GERMS.]



eggs, giving first rise to two continuous vesicles, one larger than the other, which may grow to an equal or to an unequal size—the one dilating, the other growing less, may give rise to two-half vesicles. Next, they may grow larger. Next, we observe that granules are formed. Here we have the first element of heterogeneous substance. Granules are formed within. How such changes are brought about is not understood. It is a mystery in the subject of our investigation. But that it takes place can be easily seen.

Now, these bags being full, no longer of a uniform liquid, but of a granulated liquid, will undergo the same change. They will divide into two sacs, which will grow equally or will remain unequal, and we shall have the process of separation as observed here. But as soon as granules have become numerous, there is a condensation taking place in some point. These granules agglomerate in some point, without having a membrane about them. There is simply a dense condensation of granules in one point. And this condensation will grow larger, so that the condensed sphere within the granulated liquid will successively be larger and larger; or by the side of the large one there will be several small spheres developed, growing at some distance from them, and remaining isolated. And perhaps some two such spheres will begin to separate, or a separation of the part which contains only clear granules from the part in which a condensation has taken place, will occur in this way, and then those spheres with two cen-

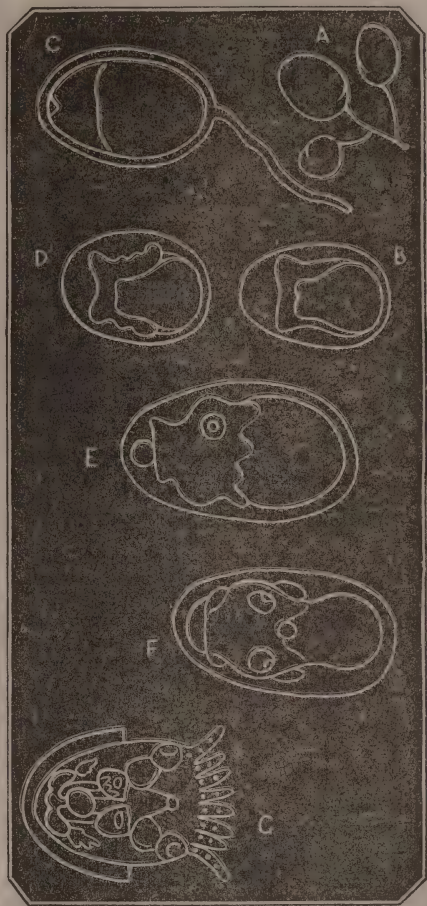
tres of concentrated mass will begin to separate, as we have here (Plate XXXVII, fig. 2) where we have two distinct spheres, with a concentrated mass in each. At this period, each of these concentrated masses is without an envelope. And now there will be an envelope formed around it. And here it will grow into a hollow vesicle; and as soon as this last process has taken place, we have a free egg. Around the spheres of condensed granules a membrane is formed, and some one or several of the granules within growing larger, give rise to a perfect egg. And so we see in the larger and still larger, those concentrated collections take place and go on developing as we have them here (Plate XXXVIII, fig. B.) with a mass of condensed yolk, swimming in a granulated liquid. And then the eggs escape from these pouches, and are laid, under their normal form. Then begins the series of modifications and repeated divisions and subdivisions which give rise to the formation of a germ to form a new individual. Now, the changes of these eggs illustrate the same time the formation of cells. They are multiplied by the division of vesicles containing a simple liquid. Condensation takes place within and around this collection of granules, and a membrane is produced. Then will appear again some granules growing within, which will be the nucleoli.

It can now no longer be doubted, that the process of formation of eggs and the process of formation of cells, are identical, as it was understood that eggs and cells, in their perfect formation, were similar organizations.

I would now proceed to illustrate the further changes of the germ of Mollusks—to show how the young of the Mollusks are developed—how they successively assume the form of the perfect animal, and how their various organs are developed. Here is a diagram (Plate XXXIX), which gives a general view of the rapid successive changes which the eggs of Cuttle Fishes undergo, in which the germ is formed around the yolk (Fig. B). After some changes, the outline of the young animal is formed (Fig. E), and after some other changes (Fig. F), it begins to resemble the full grown animal (Fig. G); and before the animal is hatched, we see it really does resemble the Cuttle Fish. (Plate XXXVI, fig. A).

You see (Plate XXXIX, fig. G.) the body, the eyes the tentacles, &c. But in order to show that all Mollusks have the same mode of formation, notwithstanding their apparent diversity, I must begin by showing you that the perfect animals themselves are constructed upon the same plan. And this is no easy task. There is no group of the animal kingdom which has been more studied, and no one which is less understood than that of the Mollusca in their morphology. I do not say that there is no group in which species are less known. On the contrary, few departments of the animal kingdom have been more extensively studied in the details—in the distinction of genera and species.

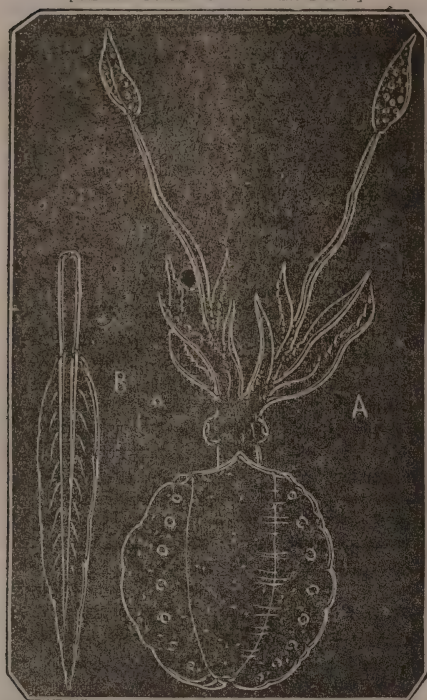
[PLATE XXXIX—EMBRYOS OF THE CUTTLE FISH.]



Thousands of them have been well figured and described. But the correspondence of their parts, from one class to another—the analogy of the different organs in their various positions—this is what is not understood in this class of animals.

That all Mollusks agree in the softness of their bodies, is well known. And this character has been constantly insisted upon as the distinguishing character of Mollusca—a soft, contractile body without articulation. This is the general character assigned to the type of Mollusca. And in addition to their character, derived from the external appearance, is usually added the fact that they have a nervous system, consisting of a circular ring around the entrance of the alimentary canal, with a swelling above and below, forming a single ring without a chain of repeated swellings, as is observed among the Articulata. But that Mollusks agree beyond this, in their structure, is so little understood, that in our descriptions, we find groups contrasted in which it is said that the gills are

[PLATE XXXVI—CUTTLE FISH.]



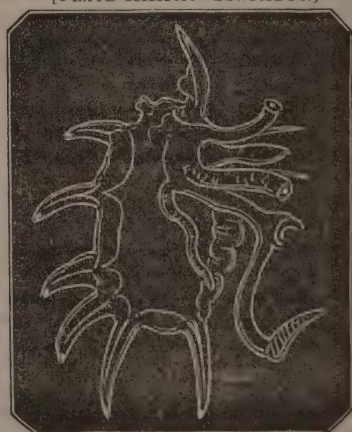
upon the back; others in which it is said that the gills are upon the sides, or on the lower side of the animal; and others in which the eyes are said to be in an entirely different position from what is observed in others. Indeed, no analogy has been, nor can properly be traced between these animals. I have, however, taken pains to trace analogy, and if I am not mistaken, have succeeded in making it out. But if I shall equally succeed in satisfying you, is another question, which you may decide after my illustrations have been made. Let us begin with an animal well known in its form and structure. Let us take the Oyster or the Scallop. If we lift one shell, we see that it is lined inside with a membrane called the mantle. The two valves of the Scallop (Plate XLIV, fig. A) as you see them drawn here on a large scale, are both lined with the mantle. On opening these two valves, you see the mantle on both sides. The membrane, as it lines the valve of the right side, is seen in Fig. B. The membrane which lines the opposite valve, which is removed, and which covers the internal organs, is removed with the shell. These two membranes lining the shells hang on the two sides of the animal. So that the mass of organs, the gills, the muscles, the liver, and alimentary canal—the whole structure is contained, as it were, between those two folds—those two membranes—as the contents of a sac within its walls. Or I may compare the shell to the coat, the lining membrane to the waistcoat, and the organs to the body within.

[PLATE XLIV—PECTEN—SCALLOP-SHELL.]



The position of the eyes is very remarkable in this animal. There is a series of eyes (Plate XLIV, fig. B) all around the margin of the mantle—about forty or fifty, or more, in number. And you see that they occur upon both sides, so that it is like a row of buttons along the coat, forming here two rows of eyes, [laughter]; and this position is so extraordinary that we may not expect to find any analogy with the Cuttle Fishes, (Plate XXXVI, fig. A), where we have two large eyes upon the sides of the head, or with Strombus, as we have in Plate XXXIII, where we have two large eyes, upon peduncles, on the two sides of the pro-

[PLATE XXXIII—STROMBUS.]



oesophagus, which comes out from the mouth. We might not expect to find these eyes about the head in any way analogous to the large number of eyes which surround the margin of the mantle.

Nevertheless, if I have understood the structure of Mollusca, I shall show that these eyes are all the same as those of the Oyster, the same as those of the Cuttle Fish, the same as those of the Strombus, the same as those of all other Mollusca. And I will try to reduce all these different forms to a few simple types, and then compare these few simple types together, in order to find, if possible, the common uniform type. The Scallop, which I have already mentioned, belongs to the so called bivalved shells—to the Acephala. And there are many kinds with regular or irregular shells, the two valves being equal in some, as in the Clam (Plate XXXV, fig. B) for instance, and in other hard-shelled animals; one being deeper than the other, one exceeding the other, and forming a beak over it, or being unequal, as the Oysters are unequal.

[PLATE XXXV.—ACEPHALA—CLAMS.]



All these differences will not modify the general arrangement of parts as seen in the Scallop. There is a mantle around the whole body; next two pairs of gills; the fleshy mass is in the centre; and above are grouped all organs, as the liver, alimentary canal, &c., &c. (Plate XLIV, fig. A)

[PLATE XXXIV—GASTEROPODA.]



In the Snail-like Mollusca, or Gasteropoda, we have, on the contrary, a large fleshy mass below, on which the animal walks. At the anterior part of the body, there is a pair of eyes upon tentacles and above the foot, the main mass of organs—the stomach, the liver, the gills—generally protected by the shell. If the shell be removed and the mantle split, we have the gills on one side, the liver on the other, the intestines winding within, the heart being near by, and the whole mass within the shell.

But among these Gasteropoda or Snail-like animals, there are many in which the body is not so complicated, or at least not twisted, but straight as in Eolis, Doris, Patella, Chiton, Emarginula, Fissurella, &c. &c. And in some of them we see that the body, for instance in Eolis, (Plate XLII fig. C) has respiratory appendages symmetrically on both

[PLATE XLV—TERBRATULA AND SPIRIFERA.]



sides, all along the upper surface of the body. So also Glaucus on both of the sides, (Plate XLII, fig. A.) So it is also in Doris, where, however, the mass of gills is placed only at the posterior extremity of the body, and has long tentacles at the anterior extremity.

But, without entering into more details, you may have already remarked that whatever differences exist between these animals in the inequalities of the two sides, we can reduce their symmetry to the regular arrangement of parts on the two sides of the body, more or less developed on one side than the other. And passing from these Snail-like Mollusca to the Cephalopoda—to the Cuttle Fishes—we shall have again (Plate XXXVI fig. A) all the parts analogous to the symmetrical Gasteropoda, the eyes and the gills are here again in pairs on the two sides of the animal.

But how will Cephalopoda and Gasteropoda compare with the Acephala, is the great question. The fleshy mass which is in the centre in Acephala, is below the mass of organs in Gasteropoda.—We have the liver, we have the alimentary canal, and we have the heart all shown. Those main organs are above the fleshy mass, and hanging over the fleshy mass, we have only the gills and the mouth.

Let us for a moment suppose that the mantle was not so long, and would not hang in such large folds on the two sides of the body, but be shorter. And let us at the same time suppose that this fleshy central part was not so contracted, (Plate XLIV, fig. B) but stretched down, and you see at once what analogy we have. You may change at once such a bivalve shall into a univalve (Plate XLIII, fig. A) with a single shell. Suppose the two

[PLATE XLIII.—MARGARITA.]



valves were united, and you will have what we observe in Patella, where there is a shell spreading on the back of the Mollusk, without any spiral on the summit; and among bivalves there are several in which the two valves are immovable; the division is well marked in youth, but they unite to-

gether in old age. This is observed in the family of Naiades, among those which constitute the genus Alasmodonta. And that the cover be shield-like or divided into two valves, does not indicate a great difference.

[PLATE XLVI.—NAUTILUS.]



We have already noticed the little value of such differences when speaking of the Crustacea, in which we had among the Entomostraca, some whose bodies were covered with flat shields, and others in which the bodies were enclosed between two moving valves, as in Cypris. Suppose this Patella was articulated in the middle, and the mantle was drawn down, there would be the first approach to the Scallop or the Oyster. Suppose that the foot was reduced to one central fleshy mass, and the analogy would then be almost complete; only the difference between the eyes and tentacles would remain.

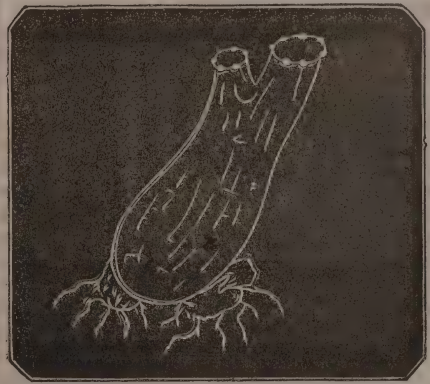
That this is no vague supposition to admit of such a division, is shown by some shells, in which there is a notch on one side, in the longitudinal diameter of the shell, for instance in Parmophorus, and in Emarginula, there is really a deep fissure. So that we pass almost gradually into the type of two connected valves, and into those which have moveable parts. Now for the eyes and for the other parts which are modified in this structure. The eyes are here (Plates XLII, XLIII,) placed around the mouth. The mantle in many of the Mollusk univalves, extends all along the shell, as you will observe in Phasianella, in Buccinum, &c. But there are no eyes except in the head. Last winter, however, it was my good fortune to meet with a little Margarita in Boston Harbor, in which we have (Plate XLIII, fig. A) tentacles all along the body; and at the base of each tentacle, are dark spots similar to the eye which is observed in the anterior part of the animal. On examination, I noticed that the mantle is constructed as it is in the Scallop. (Plate XXXVI, fig. B). We have,

therefore, here, series of eyes all around the mantle. We have even the series nearly as completely developed, as in the Pecten, and we have a fully developed eye on the anterior part of the head, on the side of which, there is one larger tentacle observed; making the analogy perfect.

But let the lateral rudimentary eyes disappear and the anterior pair remain, and we have the ordinary condition of Gasteropoda; so that the question whether there is any similarity between the Acephala and other Mollusks, must be answered by the assertion that the analogy is as complete as can ever be expected between animals of the same great department, but belonging to different classes. Indeed, in tracing the differences between the mantle of *Margarita*, (Plate XLIII,) and that of the Acephala, we notice the anterior part of the mantle has larger fringes corresponding to the region where those larger eyes occur. So that we have an uninterrupted series from those in which there are eyes all around, gradually to those which have eyes only a part of the way round, and to those which have only two eyes. Tracing, however, this structure further down, we come from Pecten to shells, as in *Mya*, where there are no eyes at all. But even in these, there are colored specks at the openings of the mantle. So that we have a natural apparatus with compound eyes, with perfect lenses, in one order of Mollusca, as they exist in vertebrata, down to those which have eyes with a rudimentary crystalline lens, and still further down to those specks which can enable the animal hardly, if at all, to distinguish between light and darkness.

Here we have a new species of a so-called soft-shelled Clam, (Ascidia) (Plate XLI,) in which the animal is included within a sac, and leaving only two openings at one end. Now on the ends of these openings we have in this—a new species,

[PLATE XLI—ASCIDIA OR SOFT-SHELLED CLAM.]



Ascidia scutella—which I have observed recently in New Bedford—colored dots. What are they? The last indication of the lowest condition of eyes on the margin of these tubes, through which water is introduced into the body. And through these, and through the open tubes of Clams, we pass gradually to those more complicated organs, as they are seen in the higher species, with a pair of eyes. From those in which we have eyes, to those in which we have only colored dots, we have gradual steps.

And in this way from the most regular Cephalopoda (Plate XXXVI, fig. A.) down to the Acephala, (Plates XXXV, XLIV and XLI) we have the multiplication of these organs, tending to transform well-defined organs into single colored specks.

In my next lecture I shall say a few words more upon the structure of Mollusca, and then proceed to illustrate their embryonic growth.

LECTURE XI.

In every type of the animal kingdom, there have been some forms observed which have perplexed Naturalists, and whose natural positions have not been ascertained until after extensive investigations. You remember with what difficulties we struggled when examining the natural circumscription of the type of Radiata; how, many animals, which had been considered as Polypi, had to be excluded from that class, as it must be circumscribed by the observations of modern investigators. Among Articulata, we felt the same difficul-

ties, owing to the peculiar structure of many parasitic Worms, of many parasitic Crustacea, which, when full grown, differ so widely from their embryonic condition, that they cannot be arranged with them, unless the whole history of their metamorphoses be ascertained by embryonic investigations. The same difficulty occurs with Mollusks.

If we had only to deal with animals with bivalve shells, with the Snail-like Gasteropoda, or with the Cuttle-fishes, as I showed in my last lecture, the general structure could be traced in their outlines,

and there would be no doubt left as to the final circumscription of that group.

But there are animals which must be referred to the type of Mollusks, according to our present knowledge of their structure, which differ so widely in their appearance from Mollusks, that, at first, when mentioned, this combination seems utterly unnatural and unfounded; and indeed, leaving the impression as if there could be no foundation for a natural system, if such combinations were to be considered as natural. Nevertheless, I think that the association of some animals which I am about to illustrate, will be found to rest on real affinity; and that the external differences in form will have no influence upon the impression which such a combination will leave.

[See Plate XXXIX, page 83.]

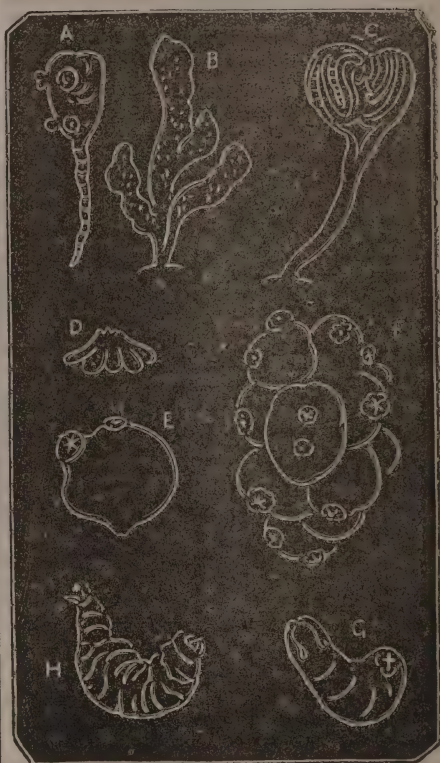
We have here in Plate XXXIX, and in several other diagrams [which the Professor exhibited to the audience.] Polype-like animals, resembling Polypi very much by their stems, with cells in which there are living animals extending and contracting in a manner similar to Polypi, with tentacles around their mouths, which act in a manner resembling Polypi still more than the stem in which they are included. And these animals do not belong to the type of Polypi; they are true Mollusks. The discovery of their internal structure was made almost simultaneously by Ehrenberg, by Milne-Edwards, and by Mr. Thompson, of Cork, so that their relation to Mollusks is now known to be very close. They have a relation to the radiated type of Polypi by the fringes around the mouth.—But the arrangement of their whole system is truly bilateral.

This figure (Plate XXXIX, fig. C) represents the alimentary canal, which differs very much from the Radiata, in being curved upon itself, in having distinct openings, a large sac which represents the stomach, and a structure which comes very near that of some animals which have never been separated from Mollusks. If we were only to consider those, perhaps the resemblance to Mollusks might have escaped observation.

But let me now trace further than I did before the analogies which exist between Mollusks. I compared the Gasteropoda with the Acephala and the Cephalopoda; I showed that there was one type in the bivalves, in the univalves and in Cephalopoda. But between the Ascidiæ (Plate XLVII), and the Clams, (Plate XXXV), there are only slight differences. Suppose the shell of the Clam (Plate XXXV) to disappear, the mantle to be almost entirely removed, the respiratory tube to be shortened, and the two openings to be somewhat remote, and we shall have such an animal as is represented in Plate XLVII, fig. H, enclosed in a sac with two openings, which are not the openings of the alimentary canal, but are the openings which lead into a cavity in which all the organs are contained.

[See Plate XXXV, page 78.]

[PLATE XLVII—ASCIDIÆ.]

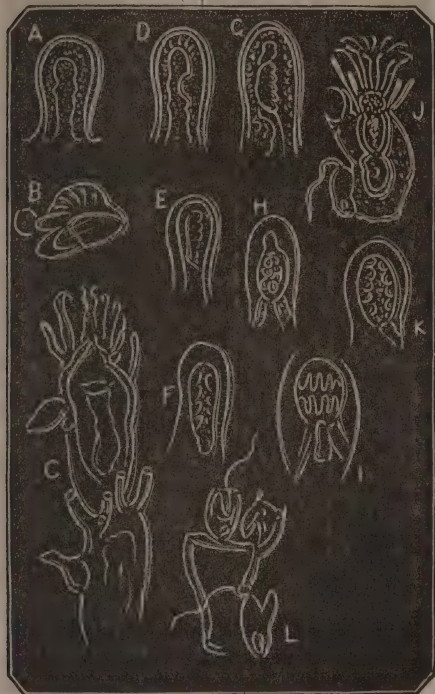


And now going further, we may have all possible modifications of this type when it is contracted and when the peduncle is attached. Plate XLVII, fig. A, represents a fixed Ascidia, the peduncle being only a prolongation of the sac-like envelope. Here we have two openings of the sac, corresponding to the two openings of the clamshell. Beyond this type, we may have one in which several individuals are united by their base. And then, from single animals, we pass to compound animals combined by their attachment on one spot, (Plate XLVII, fig. F) or by a gelatinous envelope which keeps the eggs together, (Fig. B), and constitutes compound animals.

The internal structure of these Ascidiæ, (Plate XLVII, fig. C), is so like that of Clams, that there is no difficulty about their analogy. Now, one step further, and suppose that the gelatinous envelope which unites these individuals secretes calcareous substance. Suppose further, that each individual is much smaller, and in addition, that one extremity, instead of presenting fringes at its opening, is surrounded by threads; then you have the structure of the Bryozoa. (in Plate XLVIII), with a calcareous stem, with a symmetrical alimentary canal, but with serrated tentacles round its anterior aperture, constituting a peculiar type—the Bryozoa. And that they are not

Polypi is shown when examining their embryology. Here (Plate XLVIII) are changes in one of

[PLATE XLVIII—CHANGES OF THE BRYOZOA.]



these Bryozoa, which have been investigated by Professor Van Beneden, (Fig. A). The bud-like egg which arises from the main cavity does not produce a terminal germ, from the lower centre of which the main cavity proceeds, but produces (Figs. D, G) a division of this yolk-like mass, undergoing all the processes of division which we have elsewhere observed, and finally assuming an elongated form. From the beginning it exhibits the peculiar character of Mollusks, which distinguishes them from Radiata. Their bilateral form, on the longitudinal axis, is observed in these germs. And thus, going on further, the margin becomes serrated, (see Fig. E), the internal cavity growing deeper and deeper, introducing the whole mass of yolk within, (Figs. H, K) with appendages above. These appendages will soon open, and you will have (Plate XLVIII, fig. C) a large alimentary canal, with a central cavity placed in a distinct cavity of the body, with tentacles round the opening; so that this structure is distinct from that of the Radiata.

But I must dissent from the conclusions which Professor Van Beneden has deduced from his observations. From the manner in which the yolk is placed in the interior of the alimentary canal, he concluded that there is no difference between the Radiata and the Mollusca in their embryonic growth, as the yolk is formed around the cavity,

and as the yolk is introduced from the lower side in both. But he overlooks that in Radiata the centre of development is really the centre of the mass, and that the further growth takes place in all directions simultaneously, by a uniform, all-sided development; whilst in Mollusks there is from the earliest period this bilateral and longitudinal axis. We might just as well say that the Vertebrated Animals do not differ from the Radiata, because in the former the yolk also is introduced from the lower side into the animal. But we have here another difference among Vertebrates. Besides the lower cavity, there is an upper one formed; and so we must admit that the type of Mollusk is a distinct type from Radiata, and not to be united with them.

Professor Van Beneden being one who has traced these investigations extensively, and who has tried to characterize the leading groups of animals upon the first changes of the embryo, I thought it proper to make these remarks now.

[PLATE LV—SYMBOLICAL FORMULÆ OF MOLLUSCA.]



In order to show more fully the distinguishing characters of Mollusca, compared with the other departments of the animal kingdom, I think it useful to mention here the symbols which I shall use to designate in future that type. In accordance with the mode of development of the germ in Cephalopoda, a narrow crescent, placed vertically, (Pl. LV, fig. A) would give the best image of these animals, and contrast their growth with that of Radiata, which are represented by a horizontal circle. Let this crescent be closed, it may represent the Acephala, (Fig. B,) with outward turned margins the Gasteropoda, (Fig. C,) in allusion to the wide gape of the lobes of the mantle, and with a transverse division, (Fig. D,) the Cephalopoda, alluding to the complete separation of the head.

The propriety of admitting this sign, a closed crescent, to represent the type of Mollusca, will appear much stronger, when I mention that among Cephalopoda the yolk is not entirely transformed into a germ, as it is among the Bryozoa, Acephala and Gasteropoda, only a part of the yolk being modified, so as to form a germ around the yolk.—The yolk remains for a great part unchanged, and enters the lower side of the embryo into the abdominal cavity, (Pl. XXXIX, figs. D, E.) So that we have really in outline the form of the embryonic sign, which I would preserve for the type of the Mollusca.

Among the Bryozoa there is a genus called *Pedicellina*, which is minute, and has a still more regular form than the *Eschara* and *Retepora*, resting isolated upon small stems, with fringes all

around, and a structure of the alimentary canal similar to that of the other Bryozoa. This Pedicellina shows that among the so called Infusorial animals, the Vorticellæ, placed among those which have been up to this time considered as a natural group, should be separated from them. In my opinion, Vorticellæ are closely allied to the type of Bryozoa, living separately, and constitute a fresh water genus of the type Bryozoa.

Among these Bryozoa, (Plate XLVIII,) there are some which are very remarkable for the curious appendages which surround the main parts of their body. Generally, there are some large cells, and around them smaller ones, (Plate XLVIII, fig. J.) independent buds, as it were, with threads, (Fig. F,) or with articulated joints, which shut and open like the beak of a bird, (Fig. B). What these are is scarcely understood, and I shall hardly venture to express my opinion about them.

Buds which rise from a common stem, and which differ from other buds, we have observed among Medusæ, even buds which perform different functions from others. And I can scarcely help thinking, that in these Bryozoa there are buds formed upon the same stem which will not grow in the same manner as the main individuals, but assume an entirely different shape, and will be "catching individuals," living to supply the stomach with food by seizing upon little animals, and introducing them into the cavities of the main body. To consider those appendages as parts of the main animal is out of the question, (Plate XLVIII, fig. C), as they have no true connection with them.—To consider them simply as peculiar appendages to those animals, would not be more rational. But when we see that these Bryozoa can form stems so complicated, or rather containing so many individuals, I do not see why we should not recognize imperfect individuals, like buds, assuming a peculiar form of their appendages, and then admit that they are analogous to the compound individuals of Medusæ, in which the isolated individuals do not perform the same functions, and do not resemble strictly each other. If this view be correct, I would also venture to hint at the probability of Pedicellaria in Echinoderms being a kind of budding of very imperfect individuals, resembling the lowest forms of the class, the Crinoids, and living as a sort of low parasites upon the parent, from which they differ more than any other kind of buds. Thus exemplifying those higher beings to which all sorts of parasites attach themselves constantly.

Ascidæ have a mode of development which resembles in its modifications, somewhat, the Bryozoa, but in other respects differs. The eggs of Ascidæ, which have been observed, are free when laid, and from them arise free germs. You may trace in Plate XLIX, all the phases of the development: first, the development of the yolk into spheres, which grow to form a uniform germ, (Fig. D) which divides by a deep depression (Fig. C) into

[PLATE XLIX.—DEVELOPMENT OF ASCIDÆ.]



an anterior and a posterior mass; the anterior being transformed into a sort of head (Plate XLIX, fig. A). When hatched they resemble very much Tadpoles, and they move like Infusoriæ, or rather like Cercariæ. Next appendages are developed on the two sides of the animal (Fig. E). We see that here, even in these compound Ascidians, the bilateral symmetry of the parts is still characteristic. There are no great modifications or changes in any of them after they have grown to a certain size. This external coating, which is not an egg-shell, gradually enlarges and separates more extensively from the germ itself, and finally is transformed into a shell like, or rather a membranous envelope, like this (Plate XLVII, fig. H), and the germ is transformed into an Ascidia proper, with all the structure which characterizes the perfect state of those animals—there being those two openings to the external covering (Plate XLIX, fig. J), and with those the external masses of the animal proper; so that these Ascidæ closely resemble the Bryozoa, and we pass at once from them to the bivalves. How the compound Ascidæ are developed, is not fully known, though their embryology has been traced in some instances, (Plate XLVII, fig. B.) Facts of great importance have yet to be ascertained, and I do not suppose that the facts which have been studied on the growth of compound Ascidians are completely understood, except in one class—in the Salpa—in which a wonderful alternation of generations has been observed. We have here (Plate L), those curious animals known under the name of Salpa, a kind of Acephala, which are

[PLATE L.—SALPÆ OR SOFT-SHELLED MOLLUSCA
—ACEPHALA.]

not all compound animals. Salpæ are soft shelled Mollusca, in which the transverse muscular fibres (Fig. C) are very distinct, and of which two kinds are observed. And this is the peculiarity of Salpæ, that some of them are constantly found to form long chains of distinct individuals, united by peculiar appendages, and in two rows—united side by side, and back by back, so that in a chain there are always two rows—one (Plate L, fig D) in which individuals are placed side by side; another where two such rows are united by their backs. These compound individuals swim freely about in connection together, and are never known to separate or live isolated, except, perhaps, after accidental separation. But there are other Ascidiæ observed which move free, and which are never found to unite, but which, nevertheless, in other respects, resemble so closely the former, that in tracing the internal anatomy, no difference whatever is observed. The arrangement of muscles, for instance, in such a compound Ascidia (Plate L, fig. A), or the arrangement of muscles in such isolated individuals, (Plate L, fig. C), is identical. The size of the individuals is even so similar, that this resemblance has struck observers ever since the Salpæ have been studied.

Chamisso, the poet naturalist, who accompanied Admiral Kotzebue around the world, ascertained that there was among these animals a most extraordinary mode of reproduction; that this resemblance of individuals, attached and free, could be fully accounted for. He found that within those compound Ascidian Salpæ, there were only isolated

eggs developed, as you can see, (Plate L, fig. A); that in the internal cavity there is one single egg developed from the main cavity in each of the compound individuals. And Chamisso has seen those eggs born, developed and transformed into isolated Salpæ, which would grow to the size of their parents, and when fully developed would not produce isolated eggs and isolated individuals, but a chain of individuals (Plate L, fig. C) arranged in a similar manner to the compound animals, and growing till they are born as a chain, and finally developing to the size of their grandparent, without separating, and living (as long as the observations were traced) in this compound arrangement, to reproduce in themselves isolated eggs, without ever one generation resembling the preceding. So that the compound Ascidiæ would always produce isolated eggs, from which free individuals are born; and those free individuals would always produce chains containing numerous individuals, which individuals would never separate in life, but each of which would reproduce free ones.

Over forty years these facts have been known and fully described. Chamisso has traced these in more than one instance without one link in the investigation escaping his attention. Nevertheless, these facts were so astonishing, so different from every thing that was known in the other classes of the animal kingdom, that, up to this present moment, they are not generally believed or understood. There are recent publications dated from last year, in which these statements are not admitted; though the accuracy of Chamisso is unquestioned among Naturalists—he having published other investigations which show how accurate an observer he is; and even after the investigations of Chamisso have been confirmed by other observers, there is still doubt entertained upon the correctness of the views derived from those facts.

Dr. Krohn, a German Naturalist, has traced the same phenomena in some species, which he observed on the shores of Italy. He has traced, as Chamisso did, their whole series of alternate generations without one single interruption. Steenstrup has traced similar changes. These facts have even been the starting point of his views upon alternate generations, of which I have spoken more at length before. Still more recently Mr. Sars, of whom I have so often spoken, has published the complete history of the alternate generations of several species of Salpæ, in which the whole development through alternate generations is studied and confirmed, so that we have no longer any ground to doubt these observations. We must come up to the conclusion that there are alternate distinct generations in various classes of animals. We must admit that there are animals in the Mollusca as well as in the other departments, in which the young never resemble the parent, but resemble constantly and throughout life their grandparent, as alternately these generations of compound and free Salpæ are observed.

But remarkable as it is, there are no metamorphoses observed in these animals. Very early in the young, the form of the adult is fully developed. Here is a young *Salpa* (Plate L, fig. B) developed within a compound chain, in which you observe all the principal organs as they are in the perfect animal—the muscular fibres below, as they are observed here, (Fig. C) the gill as it is also seen, the heart as it is observed in (Fig. B). The apparatus of the liver and alimentary canal, (Fig. B) separated here, but combined here (Fig. C) in one mass.

Now the phenomena of alternate generation, of which I have spoken, in the class of Worms, is more complicated than in the Mollusca, as in the Worms we have not only alternations in the generation, but also metamorphoses in each generation; this opens a field of investigation, which will present endless difficulties and endless details to ascertain, but which will certainly go to enlarge our views of animal structures and of individual life.

The embryology of the Bivalve Shell has not yet been traced to that extent to which other classes have been traced. It is remarkable that, though they are so common—though we have fresh water bivalves—though we have so many marine bivalves, and some of them so exceedingly abundant, their development has not been traced with any degree of precision. The growth of the Oyster, which might be traced every where, has never been watched by any one. Even the Muscles are very imperfectly known. Prof. Carus has observed the fact, that from a very early period, the germ (Plate LI, fig. A) of Anodonta has a tendency to divide on one side, and the other side to flatten; so that the animal assumes an oblong shape with a disc covering it from above.

[PLATE LI.—GERMS OF ANODONTA.]

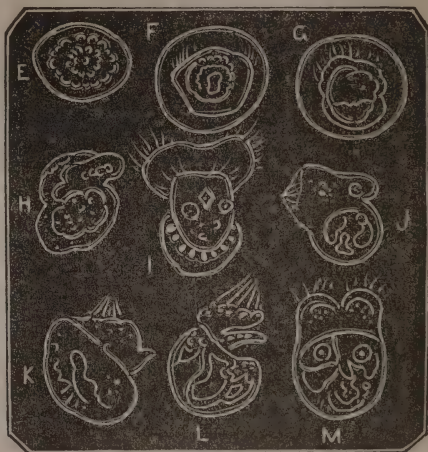


Professor Beneden says he has ascertained that those germs have been mistaken for Infusoria, and that the *Leucophrys Anodonta* of Ehrenberg is only a germ of a fresh water Clam. So that we would thus have another evidence of the heterogeneous nature of that class of Infusoria. Perhaps we should not insist so strongly upon these mistakes, when we remember how much Ehrenberg has done to illustrate the lower animals. That mistakes must have occurred constantly when the metamorphoses of the more perfect animals were less understood, is very natural. A peculiarity of the Bivalves, in their growth, consists in the fact that even those which have a foot developed as a large fleshy mass between their two valves, have, when young, only a small transverse bundle of

fibres uniting the two valves, (Plate LI, fig. D) and throw out a kind of byssus, which we observe between the muscle, in Plate LI, fig. D. This fact is important, as it shows that the shells which have a byssus above the foot, should be considered as lower than those in which the foot is more largely developed, and can be expanded and contracted between the two shells.

Lastly I would mention the changes which Gastropoda or snail-like animals undergo. During their growth they have been traced in several types. The changes of snails were early observed, more recently the metamorphoses of naked Mollusca. As they have very recently been more fully investigated, (Plate XLVIII) I would rather mention them than refer to the ancient investigation upon Pulmonatæ. Prof. Vogt has traced these investigations in a species of *Actæon* more extensively than anybody else. He has noticed that the

[PLATE LII.—ACTÆON.]



division (Plate LII, fig. E,) of the yolk goes to form a germ consisting of homogeneous cells and that after many more than twenty-four cells had been formed the external or peripheric cells assume a somewhat different aspect from the internal which would centre in the interior. And at that time the peripheric cells (Fig. F) would form a sort of envelope to the inner cells and then a division take place in the inner mass so that here also the body assumes very soon a bilateral symmetrical disposition. But what is curious is that on the sides of the anterior portion of the body, (Plate LII, fig. I) there are remarkable rotary appendages formed and between them a rudimentary foot. The upper portion (Fig. G) of the body is soon separated from the lower portion so that before the animal leaves his shell, we have (Fig. H) an upper part and a lower part and lateral wheels, by which the animal moves like the Rotifera, and a sort of foot and a sac (Fig. J) containing the various organs. Then the shell begins to be devel-

oped as a very thin membrane within the external coating (Fig. K) of the animal.

Next the yolk mass within the animal gives rise to an alimentary canal, and at that time the animal is hatched (fig. M). Before it is hatched, it resembles by no means the perfect animal. It has a shell. This is a most remarkable fact. It has a shell, though when fully grown it will resemble the Mollusca, without any shell. This shell is entirely lost before the form of the perfect animal is assumed, (Plate XLII, fig. M). These organs around the mouth are not yet distinct. Early in life, however, a hearing apparatus exists—a kind of sac, resembling the lowest form of ears, which disappears almost entirely in the perfect animal.—And the eyes are not yet seen. How these changes are brought about, has not yet been established, as the intermediate steps from this condition to the perfect animal have not yet been traced. Indeed, there is a great difficulty in all embryonic investigations, in tracing the farther growth of the germ. After they have been hatched, they die generally in confinement. It is much easier to trace it at first, than to trace it when it is undergoing its metamorphosis to assume the final form of the mature animal. And in this there is more left to investigate than in any other department of Zoology. It is even to be expected that many animals described as perfect, will be found to be only the young state of other well known animals in their full grown condition. I cannot, for instance, help thinking that the new genus established by Prof. Muller, under the name of *Astinotrocha* (Plate L, fig. F), is only a young Gasteropod of the family of Doris.

However, we can learn one great result from this fact, here—that the shell in Gasteropoda is not a character of superiority; that those animals which have a shell, so far from being of a superior type, ought to be considered as the lower ones, as there are many which have shells in their embryonic condition, and afterwards cast them. It has been ascertained by Prof. Loven that all the naked Mollusks have a shell when young, and that they all cast this shell as soon as they leave their embryonic envelope. But though I would now consider the Gasteropoda which have shells as uniformly inferior to those which are naked, this conclusion will probably not be admitted without controversy by Zoologists.

But when we consider the peculiar forms which existed among the shells of former geological ages, especially in the oldest periods, we may satisfy ourselves that this conclusion is correct.

In the first place, let me observe that these embryonic shells have a simple margin (Plate LI, fig. K). Their opening is entire as are the shells of many other Gasteropoda, the *Helix*, the *Trochus*, the *Turbo*, the *Natica*, &c. But there are many in which the margin of the shell is prolonged into a tube, a respiratory canal, as the *Fusus*, *Murex*,

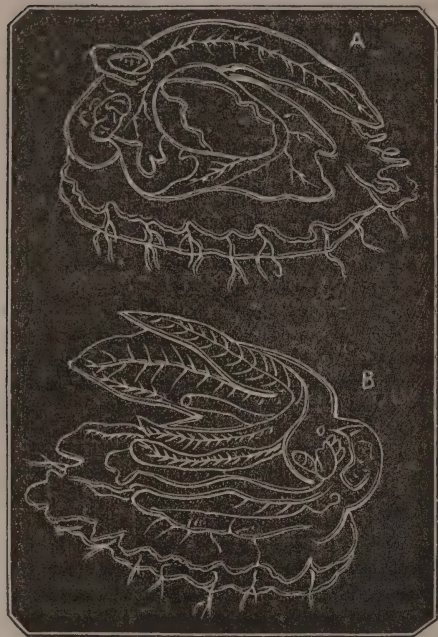
&c., through which the respiratory tube can be protruded and retracted.

Now if we are allowed to consider the order of succession of fossil animals as of any value, we would have a hint to appreciate the value of these shells. On a former occasion I proceeded precisely in a reverse way from the investigation of the types as they are well known. From their anatomy in the present epoch, I proceeded to show that the order of their appearance in geological time agrees with the gradations as they are formed in our days; and concluded that the more ancient were the lowest, because they resembled most the lowest of our days. But having once ascertained such facts very extensively, we are prepared to compare the most ancient shells with our shells, to ascertain which in the present creation should be considered as lowest, and we find that the more ancient univalves or Gasteropoda have a simple shell. And that those with a notch are of more recent date. And this is so constant that Paleontologists have not yet found one shell with a respiratory tube among those of the oldest deposits.—Then we should conclude that those which have an entire opening are lower; and those which have a notch are higher; and as those ancient shells resemble the type of the embryonic shells of the present age, we should further conclude that those which have a shell at all are lower than those which have none; and that our naked Gasteropoda should be considered as the highest in the group. But there is one point in the structure of Mollusca which is worth our attention, and which throws light upon embryonic phenomena in general, to which I will allude before concluding.

The circulation of the blood in Mollusks does not take place as it is observed in other animals. We have here (Plate LIII, fig. B) no continuous blood vessels passing from the heart into arteries, and then dividing gradually into some branches to unite again into complicated tubes—to open into the heart again—to form veins—indeed we have not a closed circulation. It is but a few years since it was known that the blood can be circulated through the body without being moved by a closed system of vessels. The impression has universally been that the circulation is regulated from a central organ propelling the blood which is circulated through vessels which go on branching into smaller and smaller tubes, and then the blood is collected again and brought back again into a central cavity; so that the circulation would imply a regular circle of this movement of the blood.

Now in Mollusca, in *Haliotis* for instance, (to describe only one case) we have blood which is moved by the heart into a tube (Plate LIII, fig. B) which is not gradually branching, and which sends out only a few vessels and then enlarges into a wide cavity. Indeed the vessel is lost, and the blood is emptied into a large cavity in the anterior part of the body. And from this cavity, arise various little vessels, which circulate through all the

[PLATE LII—CIRCULATION OF HALIOTIS, A GASTEROPOD.]



parts, which will then unite together in the veins, and those veins, before they empty into the heart, will again open into another cavity of the body, and fill it with blood; and from that cavity, the blood is introduced by tubes into the heart. Only in certain parts of the body—for instance, along the gills, and upon the glandular organs—there are regular arteries and veins (Plate LII, fig. A). But the main portion of the blood is emptied into the abdominal cavity, or emptied into another cavity around the mouth. So that in this *Haliotis*, the main stem arising from the heart, ends in a sack in which there is the centre of the nervous system, (Fig. B.) the brain of these animals, in which there are the muscles of the tongue and the beginning of the alimentary tube in one and the same cavity in which the main mass of the blood is emptied. So that the brain swims in blood—the muscular apparatus which moves the tongue swims in blood—and the main track of the alimentary canal, the alimentary tube and the other intestines swim in venous blood in the posterior cavity of the body—the most unexpected structure and apparatus of circulation, which has ever been observed among animals. And this peculiar unconnected disposition of the blood system, discovered by Prof. Milne Edwards, has been successively observed by him and by Prof. Valenciennes and Mr. Quatrefages, in all Mollusks. In the Cuttle-Fish there is a great sac in which the intestines are placed, in which they move freely, which contains venous blood, and gills and glandular organs, with their proper vessels

circumscribed with membranous tubes. What can be inferred from such a state of things, for the understanding of the embryonic changes which animals in general undergo?

We see every where in the beginning these animals consisting of uniform cells—of uniform materials. And out of these uniform materials may grow the most complicated structures. Fluid should be circulated in the parts in order that new elements should be introduced into the body. And this must be considered as brought about in the following manner.

Some of these cells will become loose, and when loose, the fluid, accumulated in the intercellular spaces, will unite in flakes, and those free cells swim within a liquid. This is blood. This blood is nothing but an accumulation of cells, which become blood corpuscles, floating in fluid within the body. Let us have the cells of an embryo, and let there be a fluid of a certain kind, and let the cells and fluid all move about, and there will be a real movement of blood. First, it is only moved forwards and backwards; but channels are gradually formed within the substance; and those channels may be lined with membrane by the coagulation of a part of the fluid. But this may take place in such a manner as to form a central cavity, which will be a heart; and to form radiating tubes, which will be arteries and veins; or to form large cavities around the main organs. Those large cavities cannot be considered as formed in another way than by the dissolution, as it were, of the embryonic substance of which they consisted primitively, and by the changes of this substance into moveable blood. The moment that the embryo has come to this point of development, it is so far advanced in its other changes that it takes food; it is hatched, and at that time new substance is introduced as food into the alimentary canal. Being digested, the result of digestion is mixed with that blood, and so the new substances are brought into the system, to undergo the changes by which it is so complicated as finally to form a most heterogeneous mass.

That the heart must be formed from the dissolution, as it were, of parts of the substance of the germ, is plainly shown by its peculiar position in so many animals. In some of the Mollusca it surrounds the alimentary canal, forming various sacs in many parts of the cavity. And this shows plainly that there we have no regular development but a sort of decomposition of the animal substance, which is gradually restored, by the formation of more and more blood, by the process of digestion.

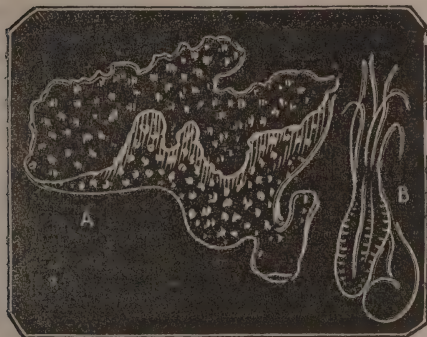
The classification of Mollusca which should be admitted if we base our classification upon embryonic data, would differ to some extent from what has been generally acknowledged.

Generally they have been divided into six classes. The Cephalopoda or Cuttle-fishes, the Gastropoda or snail-like Mollusca, the Pteropoda, of which

there are very few which differ from the Gasteropoda by having fin-like appendages on both sides of the body. Then the bivalve shells, called Lamellibranchia, and the Telebratula, under the name of Brachiopoda, and also the Barnacles or Cirripedia. That the Barnacles belong to the great type of Articulata I have already shown. The Brachiopoda ought to be combined with Lamellibranchia, having the same structure and differing only by secondary modifications, and the Pteropoda united with Gasteropoda, being merely an embryonic type of that class. In that manner three classes only remain: the Acephala or clam-like shells, the Gasteropoda or snail-like, and the Cephalopoda or cuttle fish-like.

The order of gradation of these three classes, according to their organization, is very easily established. Among Acephala the Bryozoa are the lowest, next the Ascidia, and next the bivalves; the Brachiopoda being irregular, lower than the regular ones, as the Clams.

[PLATE LIV—COMPOUND AND SINGLE BRYOZOA.]



Among Gasteropoda, the Pteropoda would be the lowest, being, as we have stated before, a mere embryonic type, reminding us of the germs of the snail-like Mollusca, which, when full grown, have a flat foot upon which they walk, among which we would place lower those which have a shell during all their life; next, and above all, the naked Mollusca, which cast their shells at an early period of their life. It is a very curious fact that the naked Mollusca are born with a shell which they often cast afterwards, showing that the shell is a character of real inferiority. And even among the Gasteropoda, provided with a shell, those are inferior

or which have the aperture entire. The order of succession in time shows that those shelly Gasteropoda with an entire aperture appeared before those which have either a long tube, or a mere notch for introducing the water to the respiratory organs.

The class of Cephalopoda will stand highest, as has always been admitted by naturalists. But we shall consider as the lowest type, those which are provided with a shell. That the chambered shells were innumerable in the former geological periods, especially in the older and middle ages, is very well known, whilst the naked ones occur most abundantly in our days; and only two genera occur in the present creation, with a shell divided into two chambers, united by a siphon.

The order of succession in time is a guide quite as safe to appreciate the gradation of types as organization itself; so that where the information upon the one point is deficient, we can refer to the other. In more than one instance we have seen it coincide in so striking a manner with the series which the intimate structure had revealed to us, that we can no longer resist such a conclusion.—We could say with confidence, that the order of succession corroborated the inferences derived from organic gradation, and, vice versa, that organic gradation illustrates the order of succession in time.

For the class of Acephala we have been able to establish a natural series, upon evidence derived from internal organization. Succession in time gives us the same series; that is to say, the Bryozoa are highly numerous in the oldest fossiliferous strata; then among the Bivalves, the Brachiopoda, which have a shell with two unequal sides, and the anterior and posterior extremities symmetrical, follow next in innumerable variety; the group of Oysters comes after the Brachiopoda, and finally the regular Bivalves, with equal sides and unequal extremities, tending towards a well marked bilateral symmetry, with diversified ends of the body, come last.

We see here the order of succession in time agrees fully with the order given by organic gradation.

It remains now only for me in my next lecture, to present a rapid and condensed sketch of the embryology of vertebrated animals, in order to show that there we have a uniform type even among the highest living beings—to conclude this course of lectures.

LECTURE XII.

We have now to examine the highest group of animals, which Naturalists have called Vertebrata. Upon this type more embryonic investigations have been made than upon any other. It was, indeed, with this type that embryological studies began—when Dollinger, the Physiologist, traced the growth of the young Chicken within the egg, and for the first time showed how important for physiological investigations it would be to understand the manner in which organs were formed, in order to arrive at more precise conclusions upon their functions. And though Dollinger has written nothing upon this subject himself, those who are conversant with the history of Embryology, acknowledge him as the first and most eminent among those who have devoted themselves to these investigations. Indeed, his pupils have, under his directions, carried out his views, and developed the new science up to the point at which it has arrived at the present day.

The most eminent among Embryologists, in this special department, (C. E. Von Baer) has been a pupil of Dollinger; and Pander and d'Alton, who first published extensive researches upon the growth of the germ within the egg of the Hen, traced their investigations under Dollinger's immediate superintendence.

That the discovery of the unity of structure among these highest animals, in their earliest condition, has not excited more interest—that the discovery of the egg among Mammalia has not been more spoken of, and has not been considered as one of the most brilliant points in the history of Physiology is, perhaps, owing to the want of a general understanding of these matters, and the difficulty there was before of comparing, properly, the egg in the various classes of Vertebrata, or of introducing this subject before the public at large, as it was done among professional men. But really, it was in Physiology a great discovery when it was ascertained that all Vertebrata, that Fishes as well as Reptiles, as well as Birds, as well as Mammalia, arose from eggs, which have one and the same uniform structure in the beginning, and proceed to produce animals, as widely different as they are in their full-grown state, simply by successive gradual metamorphoses; and these metamorphoses upon one and the same plan, according to one and the same general progress.

The unity of structure in Vertebrated animals has been ascertained, has been understood, and well understood, long before Embryology had added anything to show how deep this unity of plan was impressed upon that type. By the investiga-

tions of Comparative Anatomy, it had been ascertained that the external differences which characterize the class of Fishes, that of Reptiles, that of Birds, and that of Mammalia, were only modifications of one and the same structure—that the head of Fishes, for example, though apparently so different from that of Man, was made up of the same bones, arranged in the same manner, only subdivided into more distinct points of ossification, with modified proportions, most of them remaining moveable for life, but after all, arranged upon the same uniform plan.

It was especially in Osteology, that is, in the investigation of the bones, that this unity has been traced at full length. It is, therefore, to that subject I would particularly call your attention with reference to these general realizations, although I cannot enter here into details of an illustration of the facts. Anatomy has shown us the gradation which exists among these animals to such a degree of perfection, that in the leading and fundamental divisions there will be very little to improve, though the details may be considerably improved under the influence of embryological researches.

The order which is now assigned to the different classes of Vertebrata is, to place Fishes as the lowest class; next Reptiles; then Birds; and Mammalia at the head. And this order of classification, established from anatomical evidence, is also confirmed by the differences which exist in the mode of growth. Though starting from a common structure in the primitive egg, the different classes undergo metamorphoses, which proceed in such a manner as to end in the establishment of those final differences which characterize the structure of the different classes of Vertebrata. It is, indeed, by the difference in the process of growth that those differences which characterize the full grown animals are brought about.

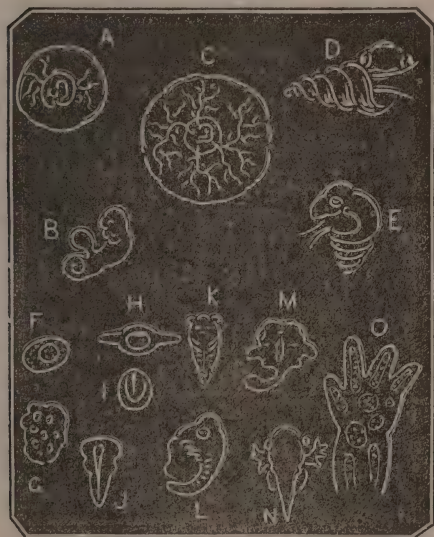
It may therefore be said with perfect propriety, that the higher Vertebrates undergo changes through which, in different periods of their life, they resemble the lower ones; that there is a period when the young bird has the structure, not only the form, but the structure, and even the fins, which characterize the Fish. And of the young Mammals the same may be said. There is a period in the structure of the young Rabbit, (in which the investigations have been traced more extensively than in any other species,) when the young Rabbit resembles so closely the Fish, that it even has gills, living in a sac full of water breathing as Fishes do. So that the resemblance

is as complete as it can be, though each of these types grows to a complication of structure, by which the young Mammal, for instance, leaving behind this low organization of the lower types, rises to a complicated structure, to higher and higher degrees, and to that eminence even which characterizes mankind.

As it is out of the question for me to introduce an illustration of all the phases of these changes, I will only introduce such points of the subject, as bear upon classification, and upon the succession of types in former geological ages, in order to show that the principle which I intend to introduce, as the fundamental principle of classification, is really of value, in all departments of Zoology.

In these diagrams you have representations of the changes which animals of the four classes of Vertebrata undergo. Here (Plate I, page 7) is the history of a Fish, (a White Fish from Lake Neufchatel), as represented by Dr. Vogt, from the egg (Fig. A) up to the period when the young Fish (Fig. F) is hatched. The close resemblance between this form (seen in fig. H) and other classes, is more striking. Here (Plate II, figs. F to O) we have the history of a Frog, (also from a paper of Dr. Vogt,) from the first moment of its formation (Fig. F.) up to the period when the young Tadpole (Fig. N) is hatched. In Plate II, figs A to E, are

[PLATE II—EGGS OF SNAIL AND FROG.]



the changes which a Snail undergoes, according to the illustrations of Rathke; and in this figure (Fig. B,) it is represented, as it appears, taken out of the egg, and deprived of its external envelope, in order to compare it with the form of the young Tadpole, (Plate II, fig. L,) or the form of the young Fish (Plate I, fig. H.) You see the Snail, in its early condition, resembles the young

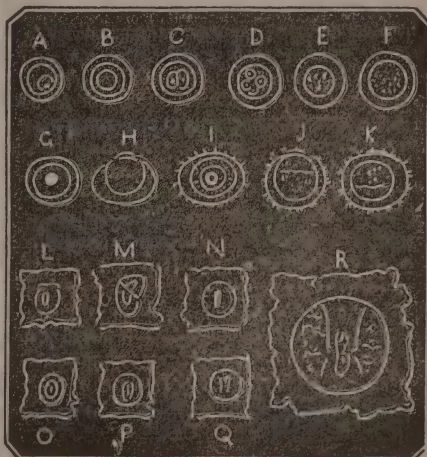
Tadpole, closely, as you may ascertain by comparison of the figures. The resemblance with the Fish is not less striking, as you see on comparing also the figures of the young Fish.

[PLATE VII.—EGGS OF BIRDS AND HENS.]



And if we go on, we shall find the same agreement in Birds and Mammalia. We have here (in Plate VII) the Hen's egg. Here, (Figs. E to K) we have the different changes within the egg, as figured by Pander and Baer. We have here the different modifications of the young Chicken within the egg; and we have here (Fig. K) the young Chicken, already formed, at one of its earlier periods of growth, when it has yet undergone slight changes of form in its progressive development; and here, (Plate IX,) as we proceed further, we have the history of the changes of the embryo of a Rabbit, from the remarkable work of Prof. Bischoff. I have not figured the outlines of all peri-

[PLATE IX—EGGS OF RABBITS.]



ods; but compare these earlier forms (Plate IX, figs. L to Q) with those of the Chicken, (Plate VII, figs. E to I,) and you see again that the outlines are identical. I might have had a figure of a young Rabbit, when the head has come to be more distinctly developed, and when the posterior part is more contracted, and the resemblance would be still greater than you notice at present, on comparing those lower figures, (Plate IX, fig. P, and Plate VII, fig. H.)

It is not only in these forms of the germ that we have an identical structure, an identical form, an identical process of the formation of the eggs, and the same identical functions; we have the same modifications in the egg to bring about the formation of a germ; and this process by which the germ is formed is identical in Vertebrata with what we have observed in Radiata, in Mollusca, in Articulata. The resemblance does not go further, but here the identity is complete. The egg of a Fish (Plate I, fig. A) consists of a yolk mass, enclosed in its membrane, and containing a germinative vesicle and a germinative dot. If we pass on to the classes which we would suppose to differ most—the Mammalia, for instance—we find that the egg of a Rabbit (Plate IX, fig. A) consists, as you see, of a vitelline membrane, a germinative vesicle, and within it a germinative dot. This is the egg in its primitive formation, as it was discovered by C. E. Von Baer, in the year 1827, when, for the first time, the unity which exists in the starting point of growth of all animals, was clearly ascertained. You remember that we observed an identical structure among other classes; and if I were to enter into the details of the changes which the egg undergoes, I should seemingly repeat only what I have said about other types. If you have not forgotten what I said about the divisions of the yolk, you will remember that the egg showed (as represented in Plate I, fig. B,) a successive division into cells, which is even more regular in Mammalia than in any other class. It is here (Plate IX, figs. C to F) symmetrical in the Rabbit, with the division into halves, and the subdivision into quarters, into eighths, into sixteenths, and into thirty-two parts, and so on, as represented in the various figures in this plate. And indeed, Professor Bischoff, who has traced all the details, represents the yolk as dividing first into two masses, then into four, then into eight, sixteen, thirty-two, and even sixty-four. Then the whole vitellus is transformed into a uniform mass of minute cells. Next a mass of somewhat different substance is circumscribed, (Fig. G,) to be the germ; so that in describing the changes of substance occurring in Mammalia, we have the same thing that we have noticed in the Worms, the Crustacea, in the Shells, and which we know to take place among Radiata. We know further, that these changes (Fig. B) will go on to form organs, and finally to produce the perfect animal.

Such a germ is formed here in Birds, (Plate VII,

fig. C). The mass in the middle of the yolk is a part of its fatty contents. There is no fundamental difference, however, from what we observe in the Mammalia; but as the substances are not so completely mixed up as in other classes, the figure, of course, represents the details as they appear. The young germ within the egg of the Fish, (Plate I, fig. C), and also in the Frog (Plate III, fig. A,) and the Snail, (Plate II, fig. A,) represents also the same condition. So that after the egg has undergone its particular changes, the germ is formed upon it, and has an identical aspect in the four classes of Vertebrates. (Pl. III. page 8.)

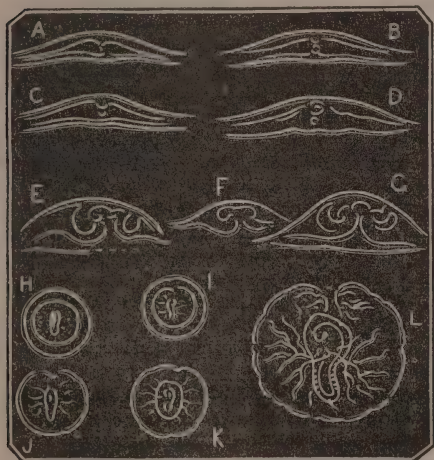
Now this germ will grow by a double process of extension. It is thickened by the assimilation or by the transformation of successively larger portions of the yolk, which is introduced into the mass by transformation of substance, and next it expands over successively larger parts of the surface of the yolk. Then the thickened substance of the germ soon divides into several layers, as is figured in the diagrams in Plate VII, fig. D, where the germ having grown larger, we may distinguish a circular outline, and another of a more elongated form; and in a transverse section of such a germ, (Plate VIII, fig. A,) we may observe that the upper portion of it has a somewhat different size from that of the lower and middle layer. So that in its thickness the germ begins to show itself by the changes which it successively undergoes. As soon as this separation of the germ into several layers has taken place, then each layer for itself will undergo changes. The upper layer, especially, is thickened within the centre; and in the middle layer there is an accumulation taking place about the centre also, and the lower layer is growing very soon beyond the upper, and beyond the middle layer. So that from the figure seen from above, (Plate VII, fig. D,) you see the outlines of the three layers at once. Successively the layers will enlarge, so as to cover the greater portion of the yolk.

How the germ extends, gradually, more and more, so as to cover a greater and greater portion of the yolk, is seen here (Plate IX, fig. J,) where the layers are seen hanging over the yolk, and finally, (Fig. K,) enclosing it in the lower cavity of the germ; or the upper parts cover only one portion of the whole surface. To shorten this illustration, let me at once say, that the upper layer is the foundation for all those organs by which animal life, properly, is maintained; by which animal life, properly, is expressed. It is from this layer that the whole frame which is acting in life, will be developed. It is from this part that the head, the legs, the walls of the body, the flesh, the bones, the brain, the organs of sense, are successively developed. The upper layer (Plate VIII, fig. A,) gives, indeed, rise to the organs of animal formation of all life; and the middle layer, on the contrary, gives rise to the formation of the heart, and the blood vessels; to the organs of the

circulation in general. And the lower layer gives rise to the organs by which life is maintained; in the first place to the various sacs of the alimentary canal, to the various parts of the digestive apparatus, the stomach, with its glandular system; the lung, which is only a sac derived from the alimentary tube, and all the other various glandular organs which are connected with the alimentary canal, and also to the liver, in connection with the blood system, and to the system of reproduction.

I need not enter into these anatomical details; but in order to show how this is brought about, let us trace, for a moment, these longitudinal sections, in which the same layer (Plate VIII, fig. E,) is represented in its proportional development. The blue mass represents the upper layer of the germ, as it has grown thicker in the anterior part of the germ. These red masses represent the middle layer (Plate VIII, fig. C,) as they have grown thicker in various parts by an accumulation of blood. And this greenish mass represents that which begins to give rise to the alimentary canal. This is a longitudinal section of the germ, (Plate VIII, fig. E,) seen from above, where we may plainly observe the upper layer. We observe that it is only elongated, and there is a depression figured here (Plate VIII, fig. A.) and below, there is a collection of cells, forming what will give rise to the development of the back bone.

[PLATE VIII—LAYERS AND LONGITUDINAL SECTIONS OF THE EGGS OF BIRDS]



But the two sides of this depression growing successively thicker and higher, will form the walls of a longitudinal furrow, and this furrow will finally be shut up by the growth of the sides, and then we have the cerebral tube gradually developed (Plate VII, fig. H). And you see that the head is scarcely indicated (Plate VII, fig. G) by a somewhat greater dilatation of that upper cavity. And after a while it is subdivided by the contractions

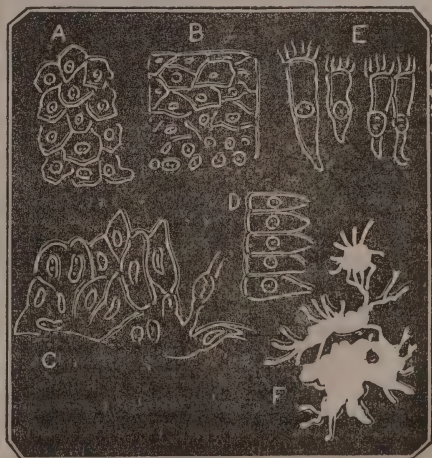
of the tube into three large cells which communicate widely with each other (Fig. H), and will represent the three principal parts of the brain.

The sides of this tube are seen first to give rise backwards to some consolidation in the mass; being not yet organized, but being cells of a peculiar form (Fig. G). The number of these is gradually increased, and in a profile view (Fig. H), you may see how the cavity (Fig. I) represents the cavity of the spinal marrow, and how the head is bent downwards, and the tail is also gradually bent downwards, so that the germ is raised above the yolk, and no longer rests flat upon the yolk, as it did in the beginning. In the earlier periods, the germ rests flat upon the yolk, and at first (Plate VIII, figs. E) the embryo lies transversely across the egg—the head and the tail bend towards each other downwards, the right hand side toward the pointed end of the egg, and the left hand side toward the other, the blunt end.

The successive modifications of the system thus sketched out, will give rise to the formation of these various systems of organs which characterize the mass of the body. The parts of animal life will be developed in the upper primitive uniform substance; solid parts will be deposited around in other places, and so the difference between hard bones and contractile substance will be introduced.

It is, perhaps, proper for me to show how this is brought about, by pointing to some figures of the modifications of cells, as they occur in the animal body.

[PLATE V—VARIOUS FORMS OF CELLS.]

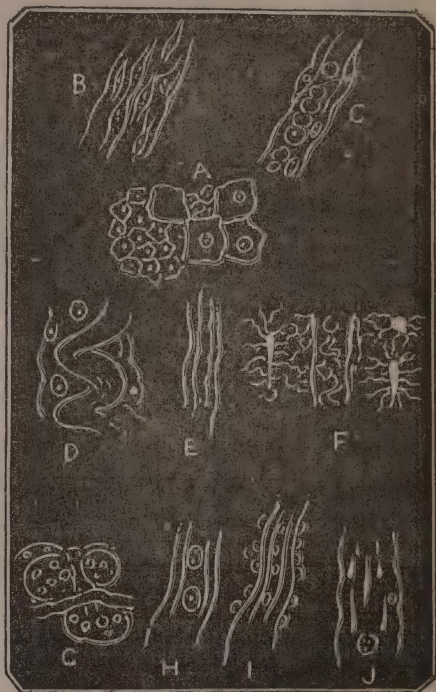


In the beginning, the embryo consists of uniform cells; but they may be elongated; they may undergo other forms by branching; they may be so elongated as to give rise to tubes; there may be various substances deposited within them, and in that way they may constitute the various modified different parts which compose the animal body. There are even some of these cells, which,

becoming loose, form the blood corpuscles, and are circulated through the system. Here are cells which line (Plate V, fig. A) the inner surface of the cavities of the body, forming the so-called epithelial membranes upon the different organs, (Fig. B.) The irregularity of the outlines of some of the forms, with their nuclei and nucleoli, still preserved, may be seen in these different diagrams, (Fig. C.) In some, the cell membrane is contracted, and assumes therefore a simple thread-like shape. There are others (Fig. D) which form a sort of pavement, and preserve their regular nucleoli and nuclei. There are some of these cells which have thus been elongated, upon whose broader flat end there are vibrating Cilia formed, which preserve, nevertheless, the nucleus and nucleolus within. That these may present different sizes in different layers, you see here (Plate VI, fig. A) in the skin of the Frog, where the external one constitutes the epidermis, and are successively cast from the surface of the skin; and the lower cells grow successively, and form a new layer, which will be again cast, and so on. How these cells may combine to form a new tissue, is here represented, where the walls of the cells are transformed into regular threads, with swellings from distance to distance. Here is another portion (Plate VI, fig. C) which we may consider as an intercellular space, with blood corpuscles circulating in it, or becoming a fleshy mass by the fixation of the nuclei, in which the walls (Plate V, fig. F) of the cells having united, will form the fibrous portion of the flesh, and in which nuclei remain for a time distinct; and here they are still more developed, (Plate VI, figs. H, I, J.) The flesh of the young animals is not yet completely fibrous; the elements of the cells constituting those masses are still to be distinguished.

Now if the cells themselves become loose and move between the spaces and other cells, then we have blood currents without walls, at first. But if there be fluid between the spaces of cells, (Plate VI, fig. C) they will form tubes, and in these tubes blood corpuscles will be circulated. The nervous substance consists still of similar elements, as we perceive here, (Plate VI, fig. D) where the nuclei are separated from the fibrous part of the nerve. Here are other cells, which, from the regular form they have in the beginning, (Plate V, fig. F) have grown into branching ramifications. And these are filled with colored matters. All those spots upon Fishes, particularly the bright spots seen upon Trouts, for instance, are only cells in which there are various colored pigments, usually different sorts of oil of various colors, and the forms of the cells differ widely as you see here. Side by side, you may have cells of different size and of different form. Even in the bone, (Plate VI, fig. F) you may have the same kind of cells, and also in the cartilages, which finally make up the hard parts of the body. There is, however, still a mystery in the manner in which these parts are introduced and carried to

[PLATE VI—MODIFICATIONS OF CELLS.]



the special parts of the body in which they have to remain. That it is the food which supplies the body with every additional particle of substance all must see, from the fact that, by eating, animals as well as men grow and increase the bulk of their various organs. But from so uniform food, there are such diversified organs produced, and with such special properties, that we cannot but wonder at the process by which it is made possible; for instance, that at some point of the body we have bones produced from the metamorphoses of food—of just those precise substances which are fit to become the peculiar substance of that particular part. How it is, for instance, that the brain is nourished, and that always those parts of the blood which can be transformed into brain substance, are carried in greater proportion into the head and into the cavity of the skull, than those parts of the blood which form and restore the fleshy masses. It is a common experience, that with the use of the arm, the fleshy mass is shortly increased. One who has not been in the habit of practising the muscles of his arm, if he begin to do so, will in a very few hours feel pain. But after a few weeks, he will notice a very considerable increase in the substance of the flesh which forms the muscular part of the arm. And this is brought about by the accumulation of those particles of the food in different parts of the body, which are fit to nourish them. That every organ has such an assimilating

power, is one of the most mysterious facts of physiology, for which we have not yet any clue.

The middle layer of the germ is that which produces the organ of circulation. First, the blood appears by a simple process of liquifaction of the cells. It can be seen under the microscope how the particles, or the cells of that layer (Plate VIII, fig. H) begin to be loose at the outer margin, and to move between themselves, and to run in particular directions, and to combine into currents, and those currents to assume particular directions, and then introduce a regular circulation before there is a heart, and before there are blood-vessels. It can be seen in every chicken under so low a magnifying power that no one should lose the opportunity of seeing this wonderful sight. When blood corpuscles move from the centre towards the margin of the germ, the other cells which become loose in the periphery of the germ (Plate VIII, fig. I) begin to move towards the centre. In the beginning, (Fig. H) there being no current circulating, the two collections of fluid meet, and finally (Plate VIII, fig. K) become regular currents by means of channels, through which the blood runs for a regular circulation.—But there are constant changes in this current, and even the ramifications of the blood-vessels are constantly changing. One channel is left, and another is formed. It is like a river on the flat lands, where the channel is constantly changing. And here the channels of the blood are constantly disappearing and are constantly reproduced.

The lower layer forms, (Plate VIII, fig. E) in the more circumscribed parts of the body, a tube which is to be the alimentary canal; and that contracted portion of the tube opens into the yolk, or a passage is formed, through which the alimentary canal communicates with the remaining yolk.

It would lead me too far to notice the successive changes which these organs undergo. I will only show that we have some remarkable differences in the successive transformations of the different classes of vertebrated animals. In the Fish, (Plate I, fig. H), the same changes occur which we have already noticed, but the final development does not come up to what we have in the Bird.

The germ, during the whole growth, is not surrounded by special envelopes derived from its own body (Plate I, fig. G); it is only the vitelline membrane which surrounds it as it rises from the yolk when the head and the tail is separated from the yolk; the germ being never enclosed in any other membrane. But now in Snakes, in Turtles, in Lizards, in Birds, and in all Mammalia, there is an additional envelope all around the embryo. And this envelope is derived from an extension of the margin of the enlarged upper layer, (Plate VIII, figs. E, F, G) which folds itself up around the germ, forming the sac of the so-called Amnios. You may trace this outline here as it extends from the lower part of the head around the navel, and folding backwards and upwards, and from behind the

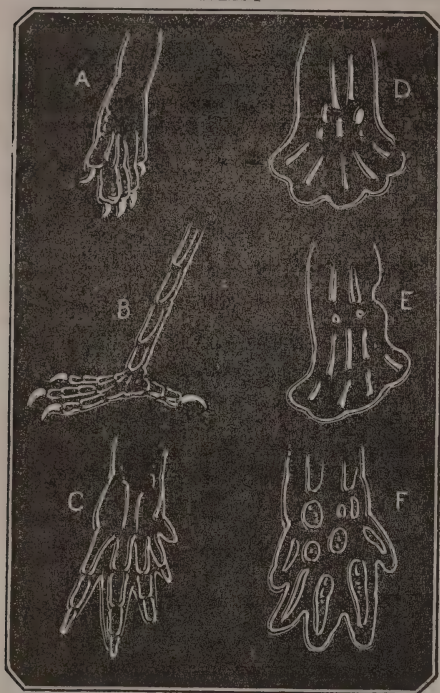
same, and from the side the same, and when these folds unite upon the back, as they do in fig. F, the germ is enclosed in another sac, though it is at the same time surrounded by the vitelline membrane, and the other substances contained in the shell.

There is, therefore, a double protection to the germ, and it is by the special development of this sac that these birds are placed in a cavity full of liquid, and during their development in this cavity, gills are formed similar to those which exist in fishes.

But there is soon another sac formed to protect once more the germ, rising in the form of a vesicle from the lower and posterior part of the body; first, a small sac growing larger, and then stretching (Fig. G) between the former sack and the envelope of the yolk membrane, so as to separate both and to extend all around the germ, forming another sac around it, the so-called Allantois. And at this period the germ is enclosed within two sacs; first, one formed from the extension of its own margin, and then another which rises as a vesicle from its lower cavity; and within these envelopes, the young chicken is developed within the hard egg-shell. Now in the Mammals, we have a somewhat different adaptation. The same process is at first going on, the same sacs enclose the germ. Suppose only the enclosing membrane of the egg not to grow hard, but to remain (Plate IX fig. K) membranous; and then we have the differences which characterize Mammalia, in which the egg remains attached to the maternal body by a peculiar development of the blood-vessels of the Allantois; when in this connection the germ undergoes all its metamorphoses before the young is born.

All the difference which exists between these animals and the lower ones of the same type which lay eggs, is only this—that in the lower classes the egg is laid with a hard envelope which is cast afterwards; while in the Mammalia the envelope of the egg goes on growing within the germ, and is not cast until the young is born. Other differences do not exist. But these changes go on to produce the great differences which we have noticed among the different classes. Unfortunately, up to the present day, Embryologists have been satisfied to have traced the first outlines of the germ, and have never considered it of any importance to trace the changes which the very young undergo to assume their final form. It struck me that it might be of some interest, and during the last Spring, I opened several eggs, at rather a late period, to see what changes they would undergo. And I was surprised to find that the first forms which are developed are not those which will be permanent. Indeed, to say it in a few words, that for instance, when the legs and wings of birds are formed, they are not formed under the shape of legs or wings. When the paws of Rabbits are developed they are not developed with their fingers as they finally grow, but appear first under the form of fins.

[PLATE X—LEGS OF MAMMALS, BIRDS AND REPTILES.]



Here is the hind leg of an adult Squirrel, (Plate X, fig. A), and here it is in an earlier stage of development, (Fig. D) Here is the foot of a Robin (Plate X, fig. B) with its covering, scales and claws; and here is the foot of a Robin at an earlier period, (Fig. E). In the Frog here, it is with distinct fingers, (Fig. C) and in the earlier periods still more different, (Fig. F).

What do we observe here? Animals which have so different organs of locomotion as the foot of a Squirrel, or the foot of a Bird, or the foot of a Frog, all have the same form originally. We may therefore say that the organs of locomotion, however diversified in their perfect state, begin under the same form. Could I have illustrated all those which I have already traced, I should have shown that the wing of a Robin is also in the beginning a fin. And indeed, in all animals, which I have traced with reference to these transformations of the young, I have found that at the first period of appearance, their organs of locomotion are throughout identical—in the Swallow as well as in the Sparrow, the Wading Birds, the Birds of Prey, and in the Swimming Birds, in all the legs and wings in their earlier condition. The legs and wings are similar to the lowest appendages or fins which we observe in Fishes, showing also that even in the first outlines of their organs there is the greatest uniformity. I may say the same with regard to the structure of the heart, of the first formation of the lungs, which

are so complicated in Mammalia. It is a simple sac in young Birds, and a simple sac in Fishes, which have also that organ in a rudimentary condition, as an air bladder, just to preserve the uniform harmony which exists in all these classes. It is obvious what important consequences such facts must have for the study of Zoology. They show at once that all animals of any given group which have webbed organs of locomotion, must be considered lower in their group than those in which this apparatus has become free—has grown independent.

To make direct application of these results to the classification of birds; let me allude to the fact, that at the present day, in our classification of birds, all the birds in which the toes are united by a web, are combined into one group—however different they may be in the structure of their wings or feathers, in the development of their inner organs, or in their mode of living. We have, in fact, in that group, the lowest birds of various types united into one very unnatural family—as we have there brought together the Penguin, having imperfect wings used as fins, with the fleetest birds. If we compare the bills, the predatory habits of some, and the low mode of living of others,—if we consider the difference between the bills of Ducks and of the Gulls,—we may conclude, after the facts above mentioned have been once ascertained, that it is likely we have combined in one group the lowest types of various families, which should be separated; and it is probable that we shall soon see a re-arrangement of the class of birds, which will be classified on other grounds, and leave in each group some swimming types and some types with divided fingers, which may be combined by some higher characters.

Already among the Vultures we have some resemblance to the Gulls, and it was only from their curved claws and hooked bills that they could not be brought together. But when I mention that within the egg, the young Robin also has a hooked bill, we see that the difference between the birds of prey and the web-footed Gulls cannot be so very great—particularly when we notice the appearance of the joints and fingers in their embryological formation, and the fact that so many birds of prey have the outer finger united by a rudimentary web. Without entering into minute details, I may state that the knowledge of the changes which each germ undergoes to assume the form of the full grown individuals, will obtain for us a complete key to the natural arrangement of the perfect animals.

Contrary to what happens in the Radiata, Mollusca and Articulata, where all classes appear *simultaneously* from the first times of development of animal life, the four classes of Vertebrata appear *successively* in different epochs of the development of our globe, in the order of gradation which Anatomy and Embryology assign to them. The class of fishes appears first; it is followed in a later epoch by

the class of Reptiles; then come the Birds and Mammalia. The class of Fishes, which I have studied more particularly, has shown me that the first types appeared under forms and with an organization peculiar to embryos of that very class in the present epoch, proving thereby with perfect evidence the inferiority of the first created types, as well in their peculiar class as in their department. But though of a lower order, these types of ancient ages bore in themselves, from the beginning, the impression of the plan that was to be successively developed in the different epochs which have preceded the order of things existing at present, and by whose realization have been brought about those numerous families of Fishes, Reptiles, Birds and Mammalia which live now on the surface of the earth. According to this plan, a certain number of families were to be extinguished before our epoch; these families are known to us only through their fossil remains, which researches in the crust of our globe have brought to light. Other families, less numerous, have lived through all the revolutions of the globe, and have preserved some representatives, a sort of reminiscence of a past order of things, confined upon a few spots of the present surface of the earth.

It is worth while to notice that Northern America is the present home of several of those ancient types. Such are, in the class of Fishes, the *Lepidosteus*, which perpetuate the order of Ganoids, in our days, an order so numerous in the fossiliferous strata of a former world, and the genus *Percopsis* of Lake Superior, which represents a family which prevailed in ancient times in Central Europe, during the epoch of the deposition of the chalk. We observe the same relation among the trees of Northern America, which resemble much more the vegetation of the tertiary period than the trees now growing in Europe.

The time has past which was allowed for this course. I must come to some conclusions without giving any further details upon the subject.

My object has been to bring the present knowledge which is possessed upon Embryology, into one point of view. If I have succeeded in showing that there is a common development to all animals, however diversified, I have succeeded in illustrating, perhaps, in a more philosophical view, the different data which have been acquired upon this point. All animals arise from uniform eggs, however different their final development may be. But however like they are at first, we soon notice the difference. The growth of the germ in Radiata does not take place in the same manner as that of Mollusca; nor does it take place as in Articulata; and we have again seen that the growth of the germ in Vertebrata takes place in a different manner. And to make this more prominent by figures, we can represent the Vertebrata, as we have done with the other great types, as follows:—by a double crescent in two opposite directions, showing that there is a special cavity containing

the brain and the main organs of sensation, and a lower cavity containing the intestines and respiratory organs. And this symbol will be only a copy of the outlines of the embryonic growth of any of these vertebrated animals.

But we have found these metamorphoses to agree in many instances with the gradation which structure had illustrated. We may therefore infer from the successive development of structure, the order in which animals should follow in a natural arrangement, as ascertained by the knowledge of metamorphosis. So that, vice versa, the study of Embryology will improve our classification, as derived from anatomical data, as well as anatomical investigation will go to complete the inferences derived from Embryology.

I think I have particularly been able to show that classification in its details may be improved by Embryological evidence. And it is upon this point I would insist: that a more extensive knowledge of young animals will be extensively useful to the further progress of Zoology, as affording, by the comparison of successive changes, the means to assign to full grown animals their respective places in any given group.

The facts are already numerous enough to allow us to consider this principle as the fundamental principle of classification, which should overrule the information derived from Anatomy in the details, as here Embryology assigns a value to the external forms for which comparative Anatomy has no understanding. Comparative Anatomy has not been able to value the external forms, to assign to them any importance. But Embryology, by the metamorphoses which take place in animals, assigns now a value to external forms, and not only assigns to them a value, but a chronological value, by which it is possible to consider as lower those animals which agree with the earlier forms of the germs.

These remarks would lead me to make some observations upon what is next to be done in these investigations. That a greater number of animals must be investigated than has been done before, is obvious. There are several animals, upon which we have no information.

But these results should not be traced simply with reference to Physiology, as it has been hitherto. All Physiologists have traced them with reference to the structure of the organs, to the structure of the tissues, to the structure of their various systems, and not with a view to understand their forms. Simple sketches of the outlines of various forms of germs from various families, with their description, would be a highly valuable contribution to the stock of our knowledge at present, and would afford, as rough as they may be, the means to place in a natural position many genera which are now placed in a most arbitrary order in our method.

I do not undervalue our past labors in classification, but I make a distinction between what has been done in an arbitrary manner, and what has

been systematically done upon real data. And when I see the possibility of leaving aside this arbitrary method of classification, I insist upon the value even of superficial comparison of all embryonic forms. And when this has been done more extensively than it has been done up to the present time, then it will be time to reconsider the whole department of Paleontology, in order to compare the forms of former periods with the early stages of growth of the animals of the present creation.

All the information about the fossils—all the information of former ages, will have to be compared with those embryonic forms, in order to understand more fully the analogy which exists between these earlier types, and the successive changes

which those of our day undergo to assume their final form. If I am not mistaken, we shall obtain from sketches of those embryonic forms more correct figures of fossil animals than have been acquired by actual restoration.

The few hints which I have been able to give are only indications towards what is to be done. The comparison, step by step, between the various fossils of all Geological periods—between the great changes which all families undergo, step by step—also remains to be done, and then the plan of the creation will be better understood. Then we shall more fully acquire an insight into these harmonies, by which the whole is combined and carried through ages to the perfection which has allowed man to stand at the head of Creation.

Erratum.—A line is omitted from the bottom of the 26th page. After the word *which*, last line, read as follows: "indeed does not come within the plan of the present course."

We subjoin a specimen of Phonography from Dr. STONE's notes. It is the first four lines of the twelfth Lecture.

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